

The AMSAT[®] Journal

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AMSAT Phase 3D Telemetry Preliminary Standard: 11 January 2001, V1.6 Peter Guelzow, DB2OS; Karl Meinzer, DJ4ZC; James Miller, G3RUH; and Stacey Mills, W4SM

The Phase 3 flight computer (IHU-1) uses a radiation hardened Cosmac CDP-1802 micro-processor running at 100K instructions/s. The operating system is called IPS, an acronym that translates as *Interpreter for Process Structures*.

A small area of the computer's 64K memory is used by IPS as workspace. This is filled with 256 bytes of data collected via a 128 channel ADC, and 128 bytes of digital data, the IPS *Syspage*. This document describes these 256 bytes, and provides support material and pointers to related information.

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Call for Board of Director Nominations

It is time to submit nominations for AMSAT-NA Board of Directors. AMSAT member societies or five current individual members may make nominations of fellow members to serve a two-year term. Four seats on a seven-member board must be filled this year. The board members whose terms are expiring are: Barry Baines, WD4ASW; Dick Daniels, W4PUJ; Robin Haighton, VE3FRH; and Bill Tynan, W3XO. Please be sure that anyone you nominate understands that meeting attendance is necessary. There are generally two Board of Directors meetings per year (Spring and Fall). Nominations should be marked Board of Director Nomination and sent to AMSAT, 850 Sligo Ave #600, Silver Spring MD 20910-4703 (**no e-mail nominations**) and must arrive by June 15, 2001.

AO-40 News Robin Haighton, VE3FRH

The following statement is addressed to those members of AMSAT-NA who have requested an explanation of the December 2000 incident that took place on AO-40. This statement has been prepared and developed by Robin Haighton, VE3FRH, President of AMSAT-NA, with input and review from other AMSAT-NA members.

As you are aware, Phase 3D was launched on November 16, 2001 into an almost perfect geosynchronous transfer orbit (GTO) by an Arianespace launch vehicle (AR-507) from Kourou, French Guiana. Within a few hours of launch excellent telemetry was being received from the 2-meter beacon, and Amateur Radio stations worldwide started downloading data with great accuracy, due in-part to the strong signal strength. The original plan was to use the 70-cm beacon, however, for reasons not yet known, the 70-cm transmitter signal was not heard.

Before the satellite could be regularly used for general Amateur Radio communications, it was necessary to carry out orbital changes, stabilize the satellite, open the solar panels, etc. The first changes to the orientation of the satellite were carried out using the onboard magnetorquing system - this worked well and after relatively few orbits the attitude of (now) AO-40 was 270/0, and ready for operation of the 400 Newton motor. Among the many components that comprise this motor system, there are several valves that control pressurizing helium and fuel. During construction of the satellite it was noted that one of the helium valves had a tendency to "stick" when operated. Both of these valves were sent back to the manufacturer for inspection and repair. Both valves were inspected and one valve was repaired, followed by return and re-installation into the system.

On the first attempt to fire the 400-N propulsion system, it failed to operate, possibly due to a sticking helium valve. Before the second attempt, it was determined that the fuel tanks could be pressurized (by helium) to their correct pressure over a five minute period, and although this was about one-tenth of the normal helium flow rate, it was still adequate for the planned three minute motor burn.

On the second attempt to fire the 400-N motor, all systems appeared to respond correctly at first. At the three minute mark the internal timer transmitted a signal for the main solenoid valve to

close, which should have shut off the fuel to the motor. Telemetry shows that the signal was sent and received, but the motor did not shut off for two or three more minutes, placing AO-40 into a higher apogee orbit than was planned at that time.

To understand how this may have happened, it is necessary to be aware that the fuel for the 400-N motor is made up of two components, hydrazine (MMH) and nitrogen tetroxide (N2O4), with each component contained in two separate tanks, both of which could be pressurized by helium. Helium could also be applied to the solenoid motor valve, the output of which operates the two fuel valves that start (and stop) the fuel flow. These valves are actually part of the 400-N motor and are located inside the motor itself.

On the solenoid motor valve there is an evacuation port that allows excess helium at the output port of the valve to escape when closing the valve. It is believed that this evacuation port was blocked and that the output port remained pressurized beyond the three-minute mark of the motor operation - thus the motor continued to burn for an extended period of time.

Between the fuel tanks and the 400 Newton motor there are fuel isolation valves that are pressure operated by the helium system. When the pressure in the helium manifold had been reduced to approximately 6-Bar (100 PSI) the fuel isolation valves closed and prevented any additional fuel from entering the motor, stopping the burn. At this time it is possible that the main motor valves were still open, due to the trapped pressurized helium that had not vented at the solenoid motor valve.

Approximately twelve minutes after the motor shut down, a second anomaly occurred. This was detected when the motor solenoid valve changed from closed to open, possibly caused by fuel migrating in the lines between the isolation valve and the 400-N motor. The motor could have also "burped" or "popped" as the fuel mixed and then ignited.

High-pressure helium (180 Bar) is fed to the motor system via a high-pressure on/off valve and a regulator valve - reducing the pressure to a nominal 15 Bar level. It is then fed to the low-pressure helium manifold. Because of the longer 400-N burn, a program for testing the high-pressure helium valve was written to "cycle" the valve (to insure proper functioning) and uploaded to AO-40.

On December 11, 2000, while cycling the helium valve, a sudden loss of signal from AO-40 occurred. It is believed that during this exercise the system became pressurized and that a leakage of fuel was the end result. Initial thoughts were that the spacecraft was completely dead and that chances of recovery were remote, with the possibility that AO-40 was in multiple pieces. However, with help from NORAD, it was determined that the satellite was in one piece with a possibility of some recovery. At least two automatic resets passed without hearing from the spacecraft. It was decided to try and hear the general beacon on the S-band (2.4 GHz) transmitter. On Christmas Day 2000 the second attempt to activate the S-band transmitter was successful, and since that day downlink telemetry has been recovered on a regular basis.

The following items have been found to be working; the 2-meter, 70-cm and 1.2 GHz receivers, the S-2 (2.4 GHz) transmitter, the magnetorquing system, the YACE camera, IHU-2 and the high-gain antennas. The following items are believed not to be working; the 2-meter and 70-cm transmitters and the omni-directional antennas.

At the time of this bulletin (16 March 2001) we still do not know the status of the Arc-jet motor - which is an important item, needed to position the satellite for future use. We do know that the satellite has lost mass, and we attribute this to the loss of bi-propellant fuel from the 400-N motor. The satellite spin rate had increased as the overall eight decreased, but by using the magnetorquing system the spin rate is now nearly down to a usable 5 RPM. In addition, the heat pipe system (which became unusable at the higher spin rates) has now become effective again.

Soon AO-40 will be able to be re-oriented so that the high-gain antennas will face the Earth, and the Arc-jet motor will be tested. Following the re-orientation it will be possible to test the remaining systems on board the spacecraft and to determine which systems and bands will be available for future operations and under what conditions.

As we all learn more about the status of the satellite, additional bulletins will be posted on AMSAT-BB, and placed on the AMSAT-NA, AMSAT-DL and AMSAT-UK web sites. Meanwhile, all those involved in the recovery of AO-40 are to be congratulated for their skills and perseverance, and may their hard work continue to bring us an operational satellite.

SUNSAT OSCAR 35 Goes Silent Hans Van De Groenendaal, ZS6AKV

SUNSAT OSCAR 35 (SO-35) has gone silent. The last communication with South Africa's first satellite was on Friday, 19 January 2001 at 1522UTC when the ground control station at the University of Stellenbosch was engaged in routine maintenance on the satellite. The ground control station made this announcement yesterday after two weeks of intense recovery action. All efforts to make contact with SUNSAT have failed. Recovery efforts will continue but the confidence level that any success will be achieved is very low.

SUNSAT was the University of Stellenbosch's first satellite and has contributed much to the development of satellite capability in South Africa. During its two years in orbit, the following original goals were established and accomplished:

- Co-operated as OSCAR-35 with the Amateur Radio and amateur satellite communities worldwide, contributing new standards in the field.
- Demonstrated high-resolution imaging not before considered possible with a satellite this size and costs.
- Stimulated challenging research and technology development at graduate student level
- Fostered valued international ties in the science and engineering community and
- Promoted science, engineering and technology among the school children of South Africa.

So-35 was launched on 23FEB99 and by 19FEB01 had completed 10,027 orbits. This translates to having traveled over 500 million km around the globe. During its operational life 51 high-resolution photographs were taken at places all over the globe, in 3 spectral bands and 15 m pixel sizes on ground. Other SO-35 statistics include:

[Continued on page 31]



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Apogee View

International Activities

AMSAT has been an international activity from the very beginning. Shortly after we were organized in 1969, the late Bill Orr, W6SAI, came to Washington and described for us a small prototype that had been built by a group of Radio Amateurs in Australia, for possible launch through Project OSCAR in California. Since Project OSCAR, by that time, was out of the launching 'business,' Bill asked if AMSAT might be willing to take this on as a first project and turn it into a real satellite.

The result was Australis-OSCAR 5. While not a communications satellite, AO-5 was the first Amateur Radio satellite to be commanded from the ground. It carried beacon transmitters on 2 and 10 meters, with which we were able to demonstrate proof-of-concept for the Mode A transponders that would later fly on AO-6 and AO-7. I was there, responsible for managing the propagation-research phase of the AO-5 program.

Including what is now AMSAT-Australia, approximately 30 national AMSAT organizations are now in existence. Some, such as AMSAT-Deutschland, AMSAT-UK and Japan AMSAT, are quite large, with many hundreds and even thousands of members. Others have only a handful, much as we did in early 1969. The newest, AMSAT-India, was formed only this year and is already planning to build a satellite. Although our legal name is still Radio Amateur Satellite Corporation and our registered trademark is still AMSAT, in recent years we have become known within the amateur satellite community as AMSAT-North America, to identify us among our international colleagues.

National AMSAT organizations communicate in a variety of ways. We have a special e-mail reflector, amsat-international@amsat.org, through which designated officers of such groups can reach each other easily. Representatives of the world's AMSAT organizations are also invited to meet once a year in person at the IARU International Satellite Forum, the site of which alternates between our annual Space Symposium and AMSAT-UK's Colloquium, which takes place at the University of Surrey the last weekend of July. This October, it will be our turn to play host, in Atlanta, Georgia. The Forum is an open meeting and I hope you'll come.

Of course, much international collaboration takes place on specific projects as well. AO-40 was one such undertaking, directed by AMSAT-DL. Right now, Amateur Radio's largest international space project by far is ARISS, Amateur Radio on the International Space Station. AMSAT organizations of more than a dozen countries are working on

that one (including partner countries and other contributors); the current chairman of ARISS is our own Frank Bauer, KA3HDO.

I mentioned IARU, the International Amateur Radio Union. If you're a member of ARRL, RAC or another national society, you're already part of this global federation. AMSAT and IARU have had a close working relationship for many years, dealing with frequency allocations for the amateur-satellite service, other ITU regulatory matters, and, of course, spectrum management. IARU is organized into three geographic regions; I represented AMSAT at the 1998 IARU Region 2 Conference in Venezuela, and plan to do so again when Region 2 meets this year in Guatemala City.

The IARU official responsible for working directly with AMSAT is Hans van de Groenendaal, ZS6AKV. Hans, a past president of AMSAT-Southern Africa and long-time SAREX telebridge operator, holds the post of IARU Satellite Adviser, which reports to the Administrative Council, IARU's top policymaking body. He is also a past president of the South African Radio League and a current member of the IARU Region 1 Executive Committee.

Under terms of reference worked out in 1994, Hans is responsible for nominating the IARU AMSAT Frequency Coordinator, whose appointment is then passed upon by the national AMSAT organizations represented at the Forum or by e-mail via amsat-international@amsat.org. At this writing, the post is vacant, so Hans is filling in on an acting basis.

This is a very important job. Satellites are inherently global, so their frequencies must be coordinated on a global basis to minimize mutual interference. Only IARU is in a position to do this, and to work with its constituent societies to establish worldwide amateur-satellite sub-bands within the Amateur bands and to protect them from interfering terrestrial operations. That includes non-Amateur interference too. We are working right now with the IARU Monitoring Service (formerly known as Intruder Watch) to help our Mexican colleagues rid AO-27 and UO-14 of unlawful taxicab interference that has been frequently noted over North and Central America.

AMSAT and IARU also worked closely together in developing a document for prospective builders and operators of Amateur Radio satellites, to help them understand the relevant legal requirements and Amateur Radio operating standards. You can find this on the Web at <http://www.iaru.org/satellite/prospective.html>.

by Ray Soifer, W2RS, Executive Vice President ■

#144	Temp - BCR #2	Temp 05	T = 0.659 * X -69.7
#145	Temp - MMH - Bay 3	Temp 06	T = 0.659 * X -69.7
#146	Temp - Aux Bat Bay 5	Temp 07	T = 0.659 * X -69.7
#147	Temp - Aux Bat Bay 1	Temp 08	T = 0.659 * X -69.7
#148	Temp - NH3 Bay 2	Temp 09	T = 0.659 * X -69.7
#149	Temp - Main bat Bay 2	Temp 10	T = 0.659 * X -69.7
#14A	***Temp - Main bat Bay 4	Temp 11	T = 0.659 * X -69.7
#14B	***Temp - Main bat Bay 6	Temp 12	T = 0.659 * X -69.7
#14C	Temp - SolPanl - 1	Temp 13	T = 0.659 * X -69.7
#14D	Temp - SolPanl - 2	Temp 14	T = 0.659 * X -69.7
#14E	Temp - SolPanl - 3	Temp 15	T = 0.659 * X -69.7
#14F	Temp - SolPanl - 4	Temp 16	T = 0.659 * X -69.7
#150	Temp - SolPanl - 5	Temp 17	T = 0.659 * X -69.7
#151	Temp - SolPanl - 6	Temp 18	T = 0.659 * X -69.7
#152	Temp - L2 Rx	Temp 19	T = 0.659 * X -69.7
#153	Temp - HP 2 +X -Y	Temp 20	T = 0.659 * X -69.7
#154	**Temp - HP 2 -X	Temp 21	T = 0.659 * X -69.7
#155	[NOT ASSIGNED]	Temp 22	
#156	Temp - S2-C Rx	Temp 23	T = 0.659 * X -69.7
#157	Temp - S1-HF Rx	Temp 24	T = 0.659 * X -69.7
#158	Temp - U Tx Exciter	Temp 25	T = 0.659 * X -69.7
#159	Temp - U & V Rx	Temp 26	T = 0.659 * X -69.7
#15A	Temp - L1 Rx	Temp 27	T = 0.659 * X -69.7
#15B	Temp - S1 Tx	Temp 28	T = 0.659 * X -69.7
#15C	Temp - S2 Tx	Temp 29	T = 0.659 * X -69.7
#15D	[NOT ASSIGNED]	Temp 30	
#15E	Temp - V Tx	Temp 31	T = 0.659 * X -69.7
#15F	Temp - U Tx PA	Temp 32	T = 0.659 * X -69.7
#160	[NOT ASSIGNED]	Temp 33	
#161	Temp - IHU	Temp 34	T = 0.659 * X -69.7
#162	**Temp - Top	Temp 35	T = 0.659 * X -69.7
#163	Temp - Bottom	Temp 36	T = 0.659 * X -69.7
#163	**Temp - Back	Temp 37	T = 0.659 * X -69.7
#165	Temp - Side 4 panl	Temp 38	T = 0.659 * X -69.7
#166	Temp - HP 4 +X +Y	Temp 39	T = 0.659 * X -69.7
#167	Temp - HP 3 -X	Temp 40	T = 0.659 * X -69.7
#168	Temp - HP 2 +X +Y	Temp 41	T = 0.659 * X -69.7
#169	Temp - HP 1 +X -Y	Temp 42	T = 0.659 * X -69.7
#16A	Temp - HP 3 +X	Temp 43	T = 0.659 * X -69.7
#16B	**Temp - N2O4 -X -Y	Temp 44	T = 0.659 * X -69.7
#16C	Temp - N2O4 +X +Y	Temp 45	T = 0.659 * X -69.7
#16D	Temp - Side 2 panl	Temp 46	T = 0.659 * X -69.7
#16E	Temp - S ant.	Temp 47	T = 0.659 * X -69.7
#16F	**Temp - Helium Tank	Temp 48	T = 0.659 * X -69.7
#170	**I - 28v - SEU	Curr 01	Use raw
#171	**I - SA-1 - BCR - 1	Curr 02	I = 0.1014 * X -0.6212
#172	**I - SA-6 - BCR - 1	Curr 03	I = 0.1014 * X -0.6212
#173	**I - SA-3 - BCR - 3	Curr 04	I = 0.1014 * X -0.6212
#174	**I - SA-2 - BCR - 3	Curr 05	I = 0.1014 * X -0.6212
#175	**I - 10V - C2 - BCR 3	Curr 06	I = 0.0125 * X -0.0875
#176	**I - SA-4 - BCR - 2	Curr 07	I = 0.1014 * X -0.6212
#177	**I - SA-5 - BCR - 2	Curr 08	I = 0.1014 * X -0.6212
#178	**I - 10V - C1 - BCR 2	Curr 09	I = 0.0125 * X -0.0875
#179	I - K - Tx	Curr 10	Use raw
#17A	I - 28V - S PA/Mix	Curr 11	I = 0.0429 * X -0.333
#17B	I - 10V - S PA/Mix	Curr 12	Use raw
#17C	[NOT ASSIGNED]	Curr 13	
#17D	[NOT ASSIGNED]	Curr 14	
#17E	[NOT ASSIGNED]	Curr 15	
#17F	[NOT ASSIGNED]	Curr 16	

AO-40 Telemetry List Analogue #100-#17F (Concluded)

Editor's Note: This article originally appeared as Version 1.4 in the October-December issue of the AMSAT-DL Journal. Since then, Version 1.6 has been published on the AMSAT WWW site. A glossary of terms used in this article is included with the WWW article. Thanks to Peter Guelzow, DB2OS and the other authors for allowing us to reprint this article. ■

TLM

Addr	Byte Name	Meaning
#180	Temporary	Used by 2MUX handler. Note: 2MUX[i] commanded with #NN i !S
#181	EPU Configuration	2MUX[1]
	bit	significance
0	LSB	Gas generator ON/Configuration ON
1		EPU run
2		Flow control 1. valve C
3		Flow control 2. valve B
4		—
5		Input valve A
6		Output valve B
7		MSB Output valve C
#182	LIU Power	2MUX[2] #AA = LIU power ON, all else is OFF
#183	EPU - Power	2MUX[3] #AA = EPU power ON, all else is OFF
#184	X-Tx Control	2MUX[4]
	bit	significance
0	LSB	AGC 0
1		AGC 1
2		AGC 2
3		AGC 3
4		—) Controls ??
5		—) reset ??
6		TWTA C0 = filament boost On control
7		MSB TWTA C1 = helix overcurrent limit override
		TX ON is 3,4MUX[5], bit 5
		TWTA ON is 3,4MUX[5], bit 13
#185	EPU - Current set	2MUX[5] #32 = 80% current; 0 = highest current CURRENT = 10.337 - 0.0366*X
#186	EPU - Flow rate	2MUX[6] #00 = min flow rate ?? Ask Dieter Zube
#187	Wheel power	2MUX[7]
	bit	significance
0	LSB	Wheel 1 power ON
1		Wheel 2 power ON
2		Wheel 3 power ON
3		— +
4		— +
5		— +
6		— +
7		MSB - +
		01010 = EPU configuration ON
NOTE: Before turning wheel power ON, speed must be set to #5FFE (0 rpm) Wheel controller will ignore OFF command until wheels have stopped spinning NEVER turn OFF 28V-S with wheels running; wheels must be despun to #5FFE		
#188	Experiment Control	2MUX[8]
	bit	significance
0	LSB	ARU ON (Array Release Unit)
1		Rudak ON
2		GPS ON
3		Mon Rx ON
4		A CAM ON
5		B CAM ON
6		Cedex control ON
7		MSB Cedex power ON
NOTE: IHU-2 ON is 3,4MUX[5], bit 8. For Monitor pre-amp to be ON, 21/24 MHz RX must be ON.		
#189	Antenna Control	2MUX[9]
	bit	significance
0	LSB	V rx to omni, V tx to higain
1		U rx to omni, U tx to higain
2		L-band omni preamp on) if bit2 & bit3 = 0 then
3		L-band higain preamp on) both are ON
4		—
5		—
6		—
7		MSB —
NOTE: See TLM byte #129 for antenna R1 position		
#18A	SEU ES Sensitivity	2MUX[A]
	bit	significance
0	LSB	20mV
1		37mV Hysteresis 200mV
2		75mV Threshold 600mV
3		150mV
4		300mV
5		600mV
6		1.2V
7		MSB 2.4V
#18B	PSU Relay Control	2MUX[B]
	bit	significance
0	LSB	main battery ON) if bit0 & bit1 = 0 then
1		aux battery ON) aux and main battery ON
2		charger ON aux/main
3		auxiliary heater ON
4		—
5		—
6		—
7		MSB —
Charger charges whichever batteries are NOT active.		
NOTE: The heater must be toggled on and off every 20ms to function.		
#18C	Battery voltage	2MUX[C] if X

AO-40 Digital Telemetry List #180 - #1FF

A New G3RUH-Type Software Modem for the DSP56002EVM

Borja Etxebarria, Itziar Martínez, Txema Rúa, Inma Hernáez

Escuela Técnica Superior de Ingenieros Industriales y de Telecomunicaciones de Bilbao, Spain

This article presents the new design of the G3RUH-type software modem. This is a two level PAM modem that works at a range of bit rates from 9600bps to 38400bps and admits different rates for transmission and reception. The major improvement of this new version is the synchronism algorithm and the structure of the reception filter. It provides a better performance of the modem. The software is aimed for the DSP56002EVM from Motorola as this is one of the most widely used platforms in ham radio.

In 1999, our research group developed a software G3RUH-type modem for the DSP56002EVM compatible with the hardware G3RUH [1] at the rates of 9600, 19200, 28800

or 38400bps based on the software version of the 9600bps modem developed by Jarkko Vuori [2]. Our version permitted the selection of different rates in transmission and reception, but presented some problems when running at 38400bps mainly due to loss of synchronism. The new version presented in this paper achieves better performance by consequence of the new synchronism algorithm and the polyphase structure of the reception filter.

Functional Structure

The structure of this modem, which is shown in Figure 1, matches the general one of a base-band modem.

The modulator consists of the first two blocks: the scrambler and the transmission filter. The next block represents the channel, which is supposed to be flat and noise additive. The rest of the blocks develop demodulation, by means of the reception filter, the AGC, the threshold detector, the synchronism recovery subsystem, the unscrambler and the DCD. In the following sections the

implementation of each block is described, with emphasis on the transmission and reception filters and the synchronism details.

Scrambler - Unscrambler

The scrambler randomizes the data to be sent providing a flatter spectrum in transmission. It also makes the synchronism process easier and reduces the DC component. The unscrambler restores the original data from the received data.

Scrambler and unscrambler are self-synchronizing and employ the same polynomial as the hardware version to provide compatibility [1].

AGC

The Automatic Gain Control attempts to maintain a constant signal level before decision. As the codec gain of the DSP56002EVM cannot be changed while running, this block acts on the sampled signal.

The algorithm searches for the biggest value of the signal within a group of samples and adjusts the gain value accordingly.

DCD

The Data Carrier Detect block validates the received data. It uses the Eye's Aperture to decide if there is any incoming data. When the Eye's Aperture is bigger than a certain threshold, the received data is valid [2].

Tx and Rx Filters

The filters were designed considering the Nyquist criterion to minimize the effect of ISI and the matched filter criterion to maxi-

mize the received SNR. The result is a set of two square root raised-cosine filters, one for transmission and another one for reception. The selected roll-off factor is the same as the first software version of [2].

The bandwidth of the raised-cosine filters depends on the selected bit rate and the roll-off factor. Table 1 shows the necessary bandwidth at each rate.

BIT RATE	ROLL-OFF FACTOR	SIGNAL BANDWIDTH
9K6	0.3	6,440 Hz
19K2	0.3	12,480 Hz
28K8	0.3	18,720 Hz
38K4	0.3	24,960 Hz
38K4	0.2	23,040 Hz

Table 1. Necessary bandwidth as a function of the bit rate and roll-off factor.

The codec of the DSP56002EVM has a maximum sample rate of 48,000 samples/s, so the maximum bandwidth of the analog input signal is 24,000 Hz. Table 1 shows that at a bit rate of 38,400bps, with a roll-off factor of 0.3, the necessary bandwidth (24,960Hz) is greater than the available bandwidth (24,000Hz). To solve this problem, the roll-off factor is reduced to 0.2.

This change of the roll-off value will produce a reduction in the performance of the modem when compared to a hardware version.

Transmission filter

The transmission filter is designed using a polyphase structure due to its multirate character.

The codec will be working at 48,000 samples per second, so the output of the filter should provide that rate of samples to the codec at all the modem rates. To achieve this, the structure shown in Figure 2 is used.

The system performs zero padding, filtering and decimation. The zero padding process, increases the working rate of the filter, leading to the figures shown in Table 2. The decimator converts the filter sample rate to the 48,000 samples per second required by the codec. Some samples will be thus ignored, and will not be calculated. This process is known as multirate filtering [3] [4].

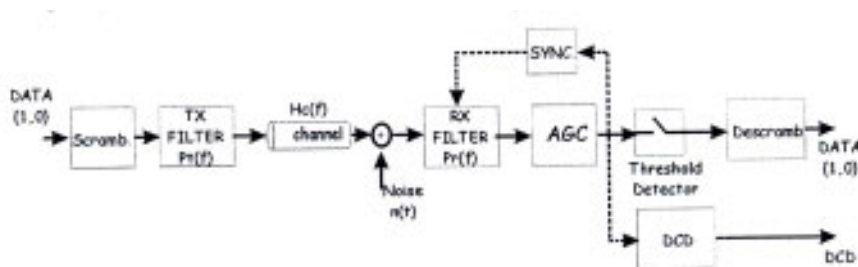


Figure 1. Functional structure of the G3RUH modem

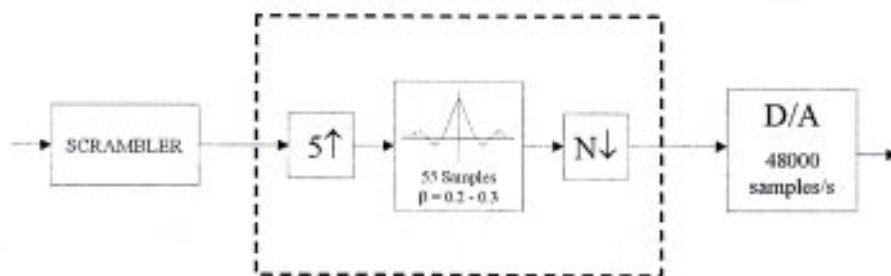


Figure 2. Structure of the transmission filter.

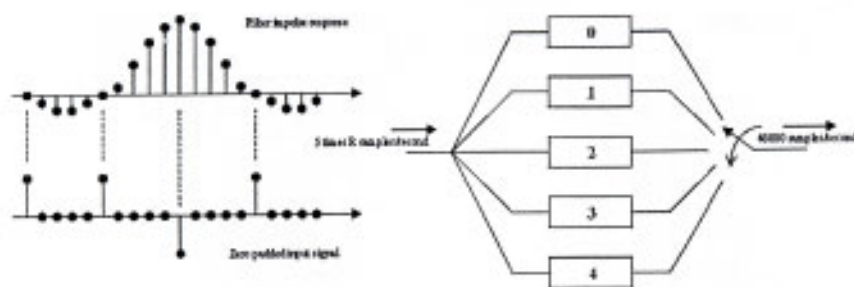


Figure 3. Multirate Processing

BIT RATE	FILTER SAMPLE	DECIMATION FACTOR	POLYPHASE SEQUENCE
9K6	48,000	1	0 1 2 3 4
19K2	96,000	2	0 2 4 1 3
28K8	144,000	3	0 3 1 4 2
38K4	192,000	4	0 4 3 2 1

Table 2. Characteristics of the transmission filter.

Figure 3 shows the multirate processing system. The filter length would be 55 samples. At the input of the filter we will find four zeros between the two data bits. If we used this zero padded sequence in the filtering process, a high number of multiplications by zero would take place. To avoid this, the filter is divided into five subfilters, called *polyphase* filters, numbered from 0 to 4 in Figure 3. Each *polyphase* includes the 11 coefficients of the filter that would not be multiplied by a padded zero input sample.

As only the samples required by the codec are calculated, a different sequence of polyphases is used at every rate and the step in the sequence is given by the decimation

factor. In this way, at the rate of 9600bps, 5 samples/bit are necessary, so we must use one output sample from each polyphase filter. At the 19200bps rate we need five samples every two bits, so we will use the output of the 0, 2, and 4 polyphases for the first bit and 1, 3 for a second bit. The sequence of polyphases used for every rate is shown in Table 2.

Reception filter

In order to perform detection the optimum decision time instant must be calculated, and the more time resolution available, the better. Thus, a high number of samples per bit should be available. In our design the demodulator can calculate up to 80 samples per bit period. However, we only need two samples to perform synchronism recovery and the detection, so just two out of 80 will actually be calculated, avoiding computing overhead.

To perform this sample rate conversion we use the same multirate filtering structure for the reception filter as the one used in trans-

mission, now with a constant decimation factor of 40 to downsample from 80 to two. The reception filter architecture is shown in Figure 4. The filter used with a roll-off factor of 0.3 is 768 samples long, and 576 for 0.2.

The interpolation factor depends on the bit rate and sets the number of coefficients of each polyphase filter. Table 3 shows the figures. At every bit rate, the interpolation factor is such that it converts from 48000 samples per second to 80 times the bit rate.

BIT RATE	INTERPOLATION FACTOR	COEFFS PER POLYPHASE
9K6	16	36
19K2	32	18
28K8	48	12
38K4	64	12

Table 3. Parameters of the reception filter.

Synchronism Recovery

The synchronism recovery algorithm uses the two samples corresponding to the center and the beginning of the bit symbol, and performs a comparison between their values. The three possible situations are shown in Figure 5. If a transition between bits has no zero crossing, the synchronism cannot operate (Figure 5a).

In case a transition occurs, we observed the value of the border sample. If it is located before the zero crossing, a variable is increased (Figure 5c). In the opposite situation, the same variable is decreased (Figure 5b).

For every received symbol, the synchronism algorithm tests the value of the variable to decide whether an adjustment in synchronism has to be done. When the variable's value is greater than a positive threshold or smaller than a negative one, an adjustment is performed by going up or down in the polyphase structure, selecting a new set of filters for the two samples to be calculated.

The up/down stepping is done with acceleration, with step values varying from one to eight. If the present necessary correction is in the same direction as the previous one, the step in the correction is duplicated, so as to reach more quickly the optimum state. If the present necessary correction is in the opposite direction or no correction has been performed during a certain number of consecutive symbols, the step value is divided by two, so as to refine the search of the optimum state.

Conclusions and Acknowledgements

A new software modem running at variable bit rates has been described. This modem

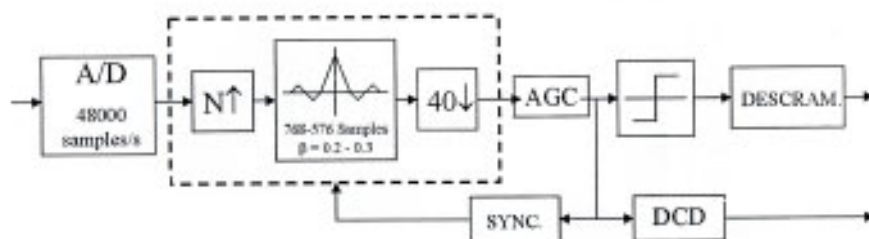


Figure 4. Structure of the reception filter.

has proved to have very good performance, even when it is compared with a hardware version of the G3RUH modem at the highest bit rates.

We would like to thank the URE (Union de Radioaficionados de España) and AMSAT-EA for the financial help given to this work.

References

- [1] Original hardware design of the G3RUH <http://amsat.org/amsat/articles/g3ruh/>
- [2] Programs for the DSP56002EVM. <ftp://wooster.hut.fi/pub/alefnul/>

- [3] Lee, E.A., Messerschmitt, D.G. "Digital Communication." Kluwer Academic Publishers (1994). ISBN 0-7923-9391-0
- [4] Proakis, R.M. "Digital Signal Processing in Communication Systems." Van Nostrand

Reinhold, Nueva York (1994). ISBN 0-442-01616-6 ■

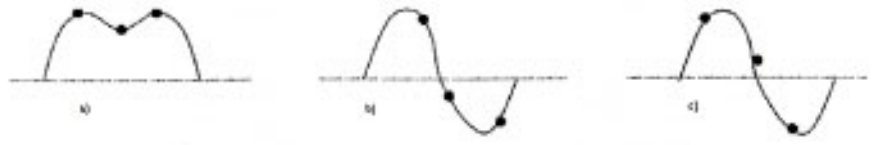


Figure 5. Possible locations of the samples in the synchronism recovery.

Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	UO-14	FO-20	RS-12/13	RS-15	FO-29	AO-27	AO-40
Catalog Number	14129	20437	20480	21089	23439	24278	22825	26609
Epoch Time	1073.52067297	1074.18605295	1073.75845546	1073.78380226	1073.56836165	1074.19361312	1073.93697131	1070.55227606
Element Set	763	643	325	333	536	399	935	48
Inclination	26.6496	98.3766	99.064	82.9232	64.8174	98.563	98.3656	5.4435
RA of Node	282.2164	137.6927	159.8084	345.0354	103.2065	312.1047	126.3703	215.5794
Eccentricity	0.5995295	0.001091	0.0540047	0.0030631	0.0166919	0.035019	0.0008462	0.8138138
Arg of Perigee	133.3302	129.534	162.8886	91.4743	243.0939	245.3642	177.7754	233.3172
Mean Anomaly	295.4668	230.6805	199.1228	268.9919	115.2842	111.0648	182.3467	23.0817
Mean Motion	2.05865472	14.30650811	12.83289026	13.74253516	11.27541097	13.52762539	14.28355049	1.26968837
Decay Rate	-0.00000238	0.00000238	-0.00000016	0.00000106	-0.00000003	0.00000057	0.00000221	-0.00000063
Epoch Rev	13349	58161	51998	50684	25599	22593	38912	166
Satellite	UO-11	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	IO-26
Catalog Number	14781	20439	20440	20441	20442	21575	22077	22826
Epoch Time	1073.97785099	1074.21938377	1074.74902418	1074.24342897	1074.71747485	1074.19044441	1073.95451627	1074.13410002
Element Set	448	442	435	454	442	158	31	919
Inclination	98.0225	98.4178	98.4304	98.4253	98.4352	98.1327	66.0874	98.3722
RA of Node	39.0524	145.4353	148.3733	147.466	149.8234	93.474	163.3684	127.3189
Eccentricity	0.0010243	0.0011273	0.0011545	0.0012241	0.001245	0.0008474	0.0015928	0.0008835
Arg of Perigee	323.779	133.9504	131.6599	133.8763	131.8206	100.089	258.6081	179.1771
Mean Anomaly	36.2723	226.2609	228.5574	226.3438	228.4043	260.1254	101.3148	180.9426
Mean Motion	14.73549897	14.30762859	14.30970547	14.30856194	14.31001659	14.38047125	12.8636077	14.28519949
Decay Rate	0.00002265	0.00000331	0.00000334	0.00000282	0.00000306	0.00000453	-0.00000037	0.00000254
Epoch Rev	91216	58164	58177	58169	58180	50686	40354	38918
Satellite	KO-25	TO-31	GO-32	SO-33	PO-34	SO-35	UO-36	AO-37
Catalog Number	22828	25396	25397	25509	25520	25636	25693	26065
Epoch Time	1074.65317900	1073.92237701	1073.84493378	1074.29771119	1073.61636850	1073.93937488	1074.85934151	1074.21388109
Element Set	901	473	627	259	318	512	643	174
Inclination	98.3689	98.6932	98.691	31.4438	28.4605	96.4609	64.5637	100.1933
RA of Node	128.0244	152.3324	151.8633	170.1196	224.1133	218.4046	2.2047	350.915
Eccentricity	0.000981	0.0002827	0.0001993	0.0363325	0.0006683	0.0153067	0.0049489	0.0038467
Arg of Perigee	157.7635	46.9609	50.0926	273.244	286.8358	46.1835	259.0291	110.7236
Mean Anomaly	202.3973	313.182	310.0428	82.6694	73.154	315.1898	100.524	249.8072
Mean Motion	14.28942169	14.22918163	14.22549949	14.25541712	15.07736088	14.41757444	14.73655415	14.34512489
Decay Rate	0.00000265	-0.00000044	0.00000119	0.00001615	0.00003264	0.00000524	0.0000099	0.0000038
Epoch Rev	35743	13915	13914	12453	13071	10809	10233	5921
Satellite	OO-38	WO-39	SAUDISAT	TIUNGSAT	SAUDISAT	ISS	OCS	Mir
Catalog Number	26063	26061	26545	26548	26549	25544	26062	16609
Epoch Time	1074.33173937	1074.19297929	1074.55353741	1073.87391839	1074.04760887	1074.80774310	1064.23572161	1076.52709779
Element Set	178	204	88	91	110	764	579	713
Inclination	100.1924	100.1905	64.5617	64.5656	64.5514	51.5705	100.1746	51.6334
RA of Node	351.0294	351.2231	32.3373	33.4397	34.6247	199.4782	0.8731	280.7512
Eccentricity	0.0038158	0.0037065	0.0022768	0.0021365	0.0022816	0.0012717	0.0029957	0.0005333
Arg of Perigee	110.249	108.3106	1.7572	347.0212	15.6938	191.3572	169.7092	156.7733
Mean Anomaly	250.2796	252.2112	358.3635	13.0326	344.4868	241.9022	190.6323	203.3497
Mean Motion	14.34569209	14.35376986	14.75087552	14.76366583	14.74160916	15.62529876	16.20008589	16.15028106
Decay Rate	0.00000367	0.00000928	0.00002586	0.00002746	0.00002047	0.00085212	0.92368558	0.00495799
Epoch Rev	5923	5924	2508	2501	2500	13249	5886	86238

Antenna Elevation Controller Using a TVRO Linear Actuator

Jim White, WD0E (jim@coloradosatellite.com)



Figure 1. The weak signal and EME array at W6OAL (The Olde Antenna Lab). The array is on top of a 55' motorized crank up tower. Only the bottom 4 Yagis elevate.



Figure 2. The linear actuator on the W6OAL array. In this photo the array is elevated about 45 degrees. The leg of the cross-tower section closest to the mast is attached to the mast with a large barn door hinge. The linear actuator is the black tube with the larger motor housing on its upper end. The fixed point on the actuator tube is attached to a bracket that extends a couple of inches from the mast. The end of the moving part of the arm (silver in this photo) is attached to a bracket which is attached to one of the legs of the tower section used as a cross boom. As the actuator arm retracts it lifts the that leg of the cross-tower and elevates the Yagi array.

Linear actuators used to turn home TV C/Ku band dishes provide an inexpensive way to position or point Amateur antenna arrays or dishes. A simple DPDT switch can be used to move the arm in or out and elevate the array. But there is no simple method for displaying the elevation in the station. A potentiometer with a weight on the shaft could be built and attached to the antenna, but this is vulnerable to wind and other problems. More expensive solutions include single package gravity actuated tilt meters. However linear actuators include a contact closure that provides pulses as the arm moves that can be read by a simple microprocessor or embedded controller and interpreted to provide the elevation readout. Today's embedded controllers combined with some very capable C language compilers make the job of building a combination control and readout quite easy.

This controller was built to run the linear actuator used to elevate the EME array at The Olde Antenna Lab, W6OAL, Parker, Colorado (Figures 1, 2, and 3). As of this writing it is in the experimental stages. This article is intended to describe the hardware and software so others may build on these ideas. This unit is a one of a kind, however these methods could be used to build similar units for other antenna installations.

The front of the control box (Figure 4) provides a switch and button to move the array up or down and an LCD display that shows the direction of movement, the pulse counts from the arm, and the elevation in degrees. The back panel (Figure 5) has connectors for the external 24 VDC supply, the 5 VDC supply, and the wires to the actuator. The back also has a combination contrast and on/off control and a serial connector for calibration and test.

Hardware Description

The schematic for the controller is shown in Figure 6. The Microprocessor (MPU) is an Atmel 90LS8535. This chip provides considerably more functionality than this application requires but was used because we had several on hand. The controller uses only the serial interface, LCD interface and three I/O pins of the MPU. The MPU is operated at 4 MHz using its internal oscillator and an external crystal. The /reset line is held high by a pull up resistor.

24 VDC is supplied from an external source to run the linear actuator motor. 5 VDC is

supplied from an external source to run the MPU and LCD display. The 5V supply is also used to provide a high to the sense pin that counts contact closure state changes from the pulse relay in the actuator.

A DB-9F connector provides a serial interface to a PC at RS-232 levels and 9600 bps. The MPU has an internal UART that provides a TTL level serial interface, a MAX202 interface chip provides the TTL to RS-232 level conversions. This interface is used only when calibrating the control unit to a particular installation and for diagnostics and testing.

An AND48GST LCD provides the display of motor direction, actuator pulse counts and elevation in degrees. It is connected to PORT C of the MPU and is a two line by 16 character display. Four data lines and three control lines are interfaced to the MPU; and three wires provide LCD power and contrast. The contrast is controlled by a 10k potentiometer that also functions as an on/off switch for the 5 V supply.

Applying 24 VDC to its motor moves the actuator. Reversing the polarity reverses the motor. ADPDT switch is used to set voltage polarity, then a SPST momentary contact button is used to turn on the motor. The voltage on the two motor leads is connected through diodes and voltage dividers to provide about 5V to two pins of the MPU. The software detects a high (+5V) on these pins to sense when the motor is on and which direction it is moving.

As the arm moves in or out a contact opens and closes in the actuator at the rate of about 20 closures (40 transitions) per inch. The 5 V supply is connected through a current limiting resistor to that set of contacts and back to an I/O pin on the MPU. A pull down resistor on that pin assures clean transitions between zero volts and about 4 V on the pin. The software detects and counts the transitions and uses them to determine the position of the arm.

Software Description

The software performs the following functions:

- Determine when the actuator motor is turned on and which direction it is moving
- Detect and count pulse transitions and maintain a count reflecting the position of the arm
- Use a formula to translate the transition count into elevation in degrees
- Display the motor direction, counts,



Figure 3. The linear actuator from another angle. Here the attachment of the fixed part of the actuator to the mast can be seen.

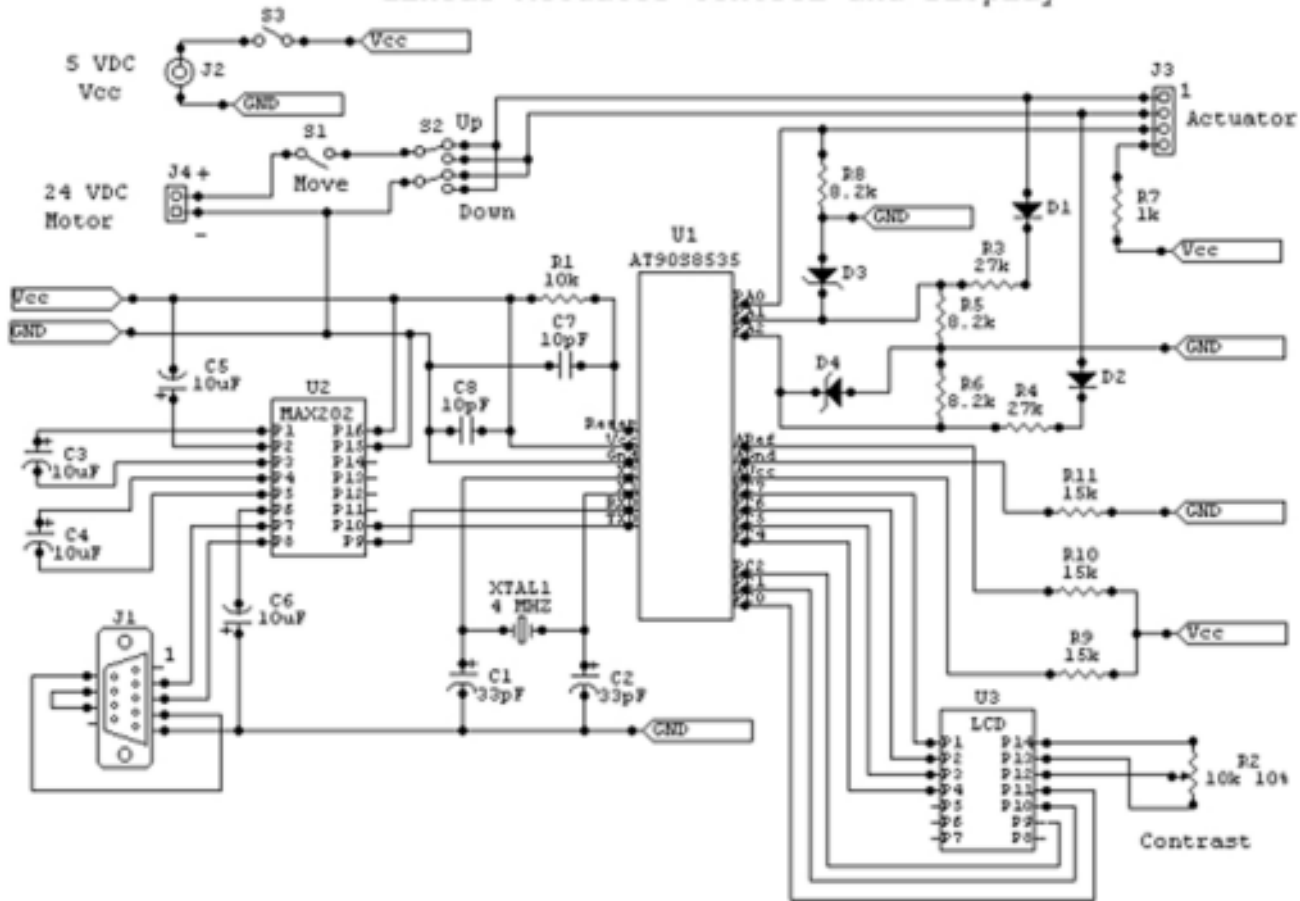


Figure 4. Front of the Elevation Controller and Display showing the button that turns on the motor on the left, the direction switch and the LCD readout.



Figure 5. Back of the Elevation Controller and Display showing the DC power connections, the connector that carries the wires to the linear actuator, the contrast control and the 9 pin serial connector for the PC calibration and test port. In this picture the 5 VDC input is erroneously labeled 12 VDC.

Linear Actuator Control and Display



Notes:

- Resistors are 10%
- J1 is a DE-9F for PC com port connection for calibration and test
- J3 pin 1 and 2 connect to the actuator motor. Set polarity to match the up/down indication on the LCD
- J3 pin 3 and 4 connect to the actuator pulse contacts, polarity doesn't matter.
- U2 is a TTL to RS-232 level converter
- XTAL 1 is computer grade 4 Mhz, 20pF loading
- U3 is a 2 X 16 LCD display AND48GST
- U1 is an Atmel AT90S or AT90LS 8535
- S2 selects direction
- S1 applies power to the motor
- S3 is part of R2
- D3 and D4 are 5V Zeners

Figure 6. Schematic for the Elevation Control and Display.

and degrees of elevation on the LCD

- Facilitate calibration by talking to a PC via the serial port
- Provide some diagnostic data on the serial port when the motor is activated

A simplified source code listing is provided in Figure 7. The full source is available at <http://www.coloradosatellite.com>. Follow the link to the W6OAL EME array.

The main loop first looks to see if the motor

is on. If it is off the **OFF** symbol is displayed on the LCD along with the current pulse count and elevation in degrees. In this **off** loop the serial buffer is checked to see if any characters have come in from the external PC. If so a case statement construct and messages to the serial port step the user through the calibration process. If the motor is on the **UP** pin is tested to determine if the movement is up or down. **UP** or **DOWN** is displayed accordingly, the **up** flag is set, and the procedure 'do_math()' is called. In 'do_math()' a formula is used to calculate

the elevation in degrees from the position of the arm as reflected by the transition count, and the counts and degrees are displayed on the LCD. They are also sent to the serial port for diagnostic purposes along with other data used when testing.

Values that must be retained when the unit is powered off are stored in the MPU's internal EEPROM. These include the zero elevation count, the 90 degrees count, the formula coefficients and the current position in counts and degrees.

```

/*
Partial source listing for Linear Actuator Elevation Control and Display
Jim White, WD0E. February, 2001
*/

bit last_pulse_state = 0; //save of last pulse high or low state
int up = 0; //moving up = 1 or down = 0
char outdata[16]; //buffer for output to LDC
eeprom int zero_ele; //counts of pulses at zero elevation.
eeprom int ninty_ele; //counts at 90 elevation
eeprom int posit; //position in pulse transitions.
int degrees = 0; //degrees of elevation
char c; //input character from UART
eeprom float mult; //counts per degree after calibration
char tmpstring[5]; //diagnostic for testing

void do_math(void) //calculate the counts, then the degrees and display
{
    if (up) posit++;
    else posit--;
    degrees = ((float)posit-(float)zero_ele) / mult;
    sprintf(outdata,"C=%4d Deg=%2d ",posit,degrees);
    lcd_gotoxy(0,1);
    lcd_puts(outdata);
    ftoa(mult,10,tmpstring);
    printf("DIAG: posit = %d, mult = %s, degrees
    %d\n\r",posit,tmpstring,degrees);
}

void main(void)
{
    printf("\n\rElevation Control starting\n\r");

    while (1) {
        //Loop till power comes on up or down
        while(PINA.1 == 0 && PINA.2 == 0) { //No power
            lcd_gotoxy(0,0);
            lcd_putsf("ELEVATION OFF ");
            //last position
            sprintf(outdata,"C=%4d Deg=%2d",posit,degrees);
            lcd_gotoxy(0,1);
            lcd_puts(outdata);
            //if a char in the serial buffer then user wants
            if (rx_counter > 0) {
                c = getchar(); // to start calibration
                switch (c) {
                    case '0' :
                        posit = 100;
                        zero_ele = posit;
                        printf("\n\rZero location saved.");
                        printf("\n\rMove elevation to ninty degrees and hit 9 ");
                        break;
                    case '9' :
                        ninty_ele = posit;
                        mult = ((float)ninty_ele - (float)zero_ele)/90;
                        ftoa(mult,10,tmpstring);
                        printf("\n\rmult = %s",tmpstring);
                        printf("\n\r90 degree elevation saved.");
                        printf("\n\rCalibration complete");
                        break;
                    default :
                        printf("\n\rStarting calibration.");
                        printf("\n\rMove elevation to zero degrees and hit 0 ");
                        break;
                } //switch
            } //if character in buffer

        } //while no power applied
        //Power is applied
        lcd_gotoxy(0,0); //See if we are going up or down
        if(PINA.1) {
            lcd_putsf("ELEVATION UP "); //And show it
            printf("Elevation up posit = %d\n\r",posit);
            up = 1;
        }
        else {
            lcd_putsf("ELEVATION DOWN");
            printf("Elevation down posit = %d\n\r", posit);
            up = 0;
        }
        //Now count pulses
        while(PINA.0 == last_pulse_state) {}; //loop till pulse state changes
        last_pulse_state = PINA.0; //save this as last state
        printf("pulse\n\r");
        do_math(); //go calc the degrees and display
    } //while 1
} //main

```

Figure 7. Partial listing of the C language source code for the microprocessor. See the text for a URL where you can get the full source listing.

The software in the included source listing is written in CodeVision AVR-C for the Atmel micro-controllers (see *Tools, below, for sources and availability of tools used in this project*). This is a very capable integrated development environment. We used the Standard version that includes a code generation 'wizard'. The program was built by first using the wizard to create a shell of source code with the functions we needed. We simply started up a new project and selected the functions we wanted. For this project we told the wizard to build the following code:

- The interrupt driven UART interface at 9600,N,8,1. Interrupt on receive only.
- The LCD interface and what port it is on (the 90LS8535 has four 8 bit ports called A, B, C and D.)
- How to initialize the port pins we are using to sense motor motion and count pulses (PORT A)
- Turn off all other features we are not using.

The wizard then built about a two-page C source code listing with all the initialization code for the MPU and the functions we needed. It included a main process loop with a comment line inside that said "/ put your code here".

We entered only the code shown in Figure 7, including the EEPROM flag on those variables we wanted to store in the internal EEPROM so they persist when power is turned off. The wizard, combined with the built in functions in the IDE such as the LCD interface, made the task of writing the code to do what we needed in our application quite simple. We didn't have to figure out how to talk to the LCD, how to get characters in and out of the serial port, or even how to store data permanently in the EEPROM.

Calibration

Unpleasant weather has prevented the integration of the controller to the array. The following section discusses the calibration method currently programmed into the MPU, a method of calibrating an array like this that might be used and the method we intend to use when Mother Nature allows.

The only time a PC needs to be connected to the controller is when calibration is to be performed. The current MPU program includes a calibration process that uses the 0 and 90-degree elevation transition counts and assumes a linear relationship between counts and the elevation of the antenna.

The calibration process starts when the user hits any key on a terminal connected to the controller's serial port. The software sends a prompt message telling the user to move the antenna to the zero elevation position and hit '0'. When the user hits '0' the transition count of 100 is stored in the EEPROM as the zero elevation count. That value was chosen to avoid negative numbers (although it wouldn't really matter if we set this to zero counts and had a negative count if the array went below zero elevation). Note that the zero elevation position will always be 100 counts regardless of the position of the arm when at zero elevation. The user is then prompted to move the array to 90 degrees and hit '9'. When they hit '9' the counts for the 90 degree position of the arm is stored, the difference between the two (-100) is calculated and that value is divided by 90. This results in a multiplier factor that is stored in EEPROM. The user is then sent a message indicating calibration is complete. From this point the counts are divided by the multiplier factor to determine and display the elevation in degrees.

As noted above this method assumes the length of the arm relative to the elevation of the antennas can be expressed by a linear function (elevation = transition count / calibration factor). In practice this relationship will depend on the mechanical linkage between the arm and the antenna array. For most installations it is likely a more complex formula will be needed to accurately calculate degrees from pulse transitions. Unfortunately no single formula is going to work in every installation.

In the W6OAL EME array the actuator is attached to the vertical mast and cross tower section to form a triangle. If we look at this as a trigonometry problem, the mast and cross tower are two unequal fixed length sides of the triangle while the arm of the actuator forms the third side. As the arm moves in and out the length of the actuator side changes and the angle between the mast and cross tower changes reflecting the elevation of the antennas. The elevation angle is that included by the mast and cross-tower and is opposite the actuator arm side. Consulting a trigonometry reference, we find the formula for relating the length of the actuator side of the triangle to the angle opposite is:

$$A = \text{ACOS}\left(\frac{b^2 + c^2 - a^2}{2bc}\right)$$

where:

A is the elevation angle,

b and c are the adjacent fixed length sides, and

c is the opposite side (the actuator arm length).

To calibrate the controller we might carefully measure the distances between the hinge and the attachment points of the arm to get b and c, carefully measure the length of the actuator arm relative to pulse transitions to get a over the range of zero to ninety degrees of elevation, then plug those numbers into this formula to get the elevation angles A. However the accuracy of the result would depend on our ability to precisely measure all those lengths, which is not an easy task given the construction of the brackets and the fact that this assembly is on top of a tower.

The method we will use is much faster, easier and more accurate. It is essentially an end-to-end measurement of the system. We will temporarily attach a protractor with a weighted string at its center to the two vertical legs of the cross-tower to provide an elevation angle measurement. First we will move the array to zero elevation and tell the software we are there. We will then move the array up to 90 stopping every 5 degrees to manually record the elevation in degrees and the counts as provided by the software. This will give us a table that relates angle to tran-

sition counts. The next step is to find a formula that expresses that relationship. For this we will use a very nice shareware program called *CurveExpert* that I have used to derive the calibration curves for telemetry values on several satellites. We will simply enter the table of recorded values (elevation vs. transition counts) into the *CurveExpert* input screen and with a few mouse clicks tell it to fit the curve and give us the formula and its coefficients. We will first try the simplest case, the quadratic equation.

$$\text{angle} = ax^2 + bx + c$$

Where:

angle is the elevation angle in degrees,

x is the transition counts, and

a, b and c are provided by *CurveExpert*.

But if that will not fit the OAL curve there are a couple of hundred built-in formulas *CurveExpert* will test against the data looking for the one that best fits. We may also enter the ACOS formula above and let *CurveExpert* determine the coefficients. Either way measuring the input data (degrees) and the resulting counts, then deriving a formula to fit that table is more accurate than trying to measure multiple mechanical variables in the system and build a formula from them.

When we see what formula will fit the data for the OAL array we will change the `do_math()` routine in the MPU program to use that formula to calculate degrees and remove the sections of the calibration routine that are not applicable.

Construction

Nothing about the construction of this controller is particularly critical. Wire length, parts placement, enclosure and connectors can all be done with just about whatever you have available (Figure 8). The most sensitive area is probably the placement of the crystal and its associated capacitors, which need to be as close to the MPU as possible. The next most sensitive issue may be the length of wire from the controller to the actuator, which needs to be short enough or large enough to assure a reasonable voltage drop. We used a plastic enclosure but a metal one may be a good idea to shield the electronics from RF especially if used in a high power HF station.

Tools

The code for the MPU was developed using the *CodeVisionAVR* C language integrated

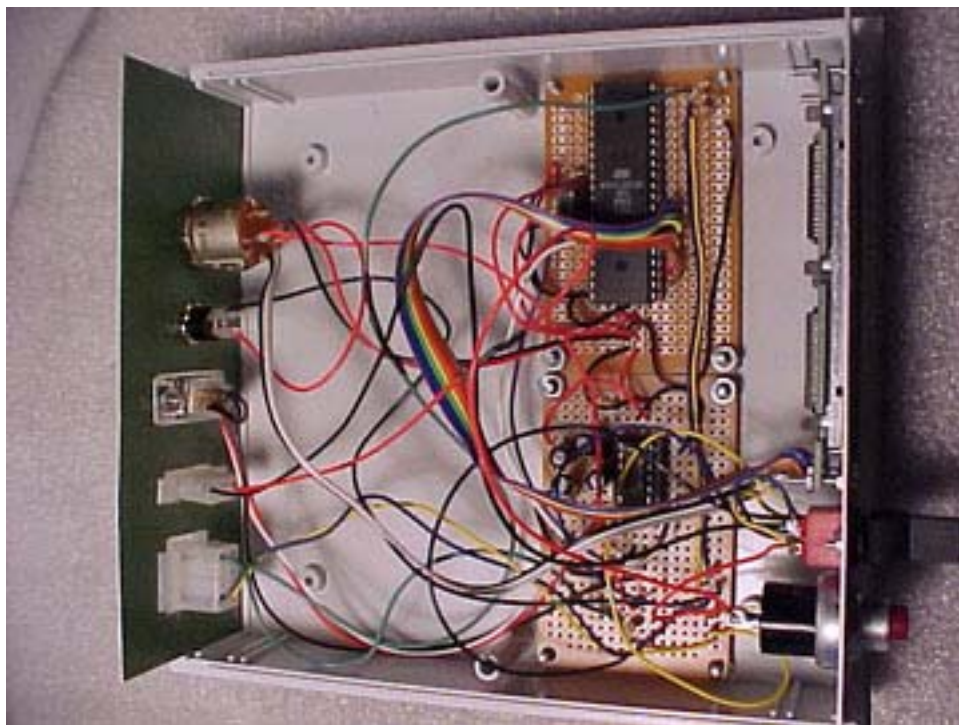


Figure 8. Two Radio Shack proto boards are mounted inside the control box. The Atmel 90LS8535 is the large IC on the right, the TTL to RS-232 converter IC is on the left. The remainder of the parts are placed as needed on the boards.

development environment (IDE) from HP InfoTech S.R.L. We run it on a Pentium 150 PC with a 17" monitor. The parallel port is connected to an STK200 development board from Atmel. That board allows us to plug in any of the AT90 series MPUs and program and test them. It provides pins to access all the ports, the UART, etc, as well as provid-

ing power for the chip. We built up the electronics for the controller on a plug in proto-board with an old actuator connected for testing. Then we plugged a 90LS8353 into the STK200 and wired the sense pins between the STK200 and proto-board. The process of making a code change and testing it takes just a few seconds and is delightfully

easy. You simply use the provided editor to make the change and click on a tool bar button. The IDE does the rest: compile the C code, assemble it into an AVR object module, program the flash memory in the MPU and start it running. It is so fast and easy it lends itself to lots of experimentation.

CodeVisionAVR is available at <http://infotech.ir.ro>. We used the Standard version which is the full featured commercial product and costs about US\$150. Less capable and less expensive versions are also available. There are a couple of other similar C language IDEs also available with varying sets of features and a range of costs. For Linux there is a set of GNU tools available.

The STK200 evaluation board is available from several sources on the web. A search for Atmel products will turn up a number of vendors. Stock varies among them so you may have to search around and perhaps make some phone calls to find one. They should cost less than US\$100.

Atmel processors are also available from numerous vendors. Stocks were low during the latter part of 2000 but there seem to be plenty available now. The AT90LS8535 is about US\$8 in small quantities. A controller like this could also be built around the Microchip PIC series parts. Similar tools are available for them.

We bought the parts we didn't have in the junk box from Allied and DigiKey on the WEB but many other vendors had them as well. CurveExpert is available through <http://www.ebicom.net/~dhyams/cvxp.htm>.

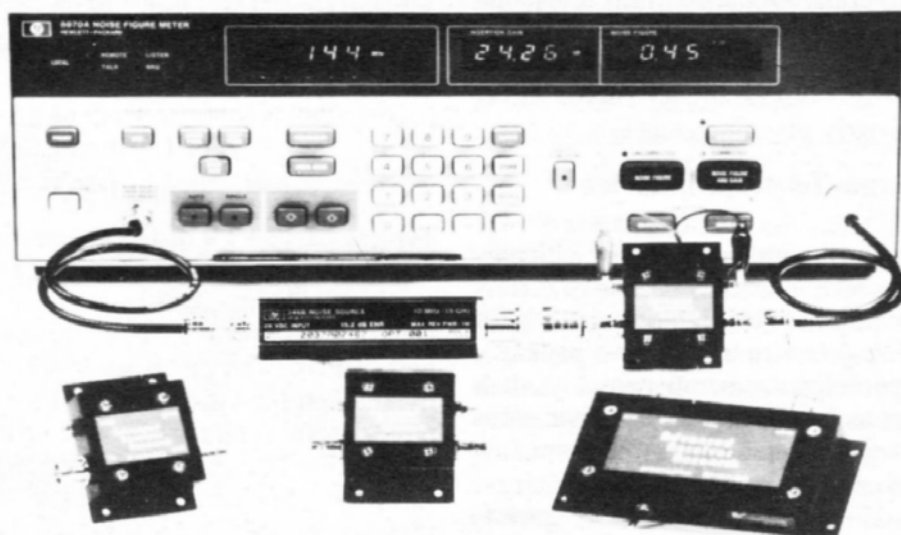
Disclaimer

This is an experiment. The author is not responsible for results those using this software, circuits or ideas may or may not achieve. The author has no relationship with any of the suppliers except that of a satisfied customer.

Summary

The purpose of this article was primarily to show how modern multi-function microprocessors can be used to provide the position read-out from linear actuators in antenna installations. In the process we hope we also provided some ideas about how one might build an actuator into an antenna system. We also hoped to show how easy it is to create software for projects like this using modern software development tools. Applications for microprocessor-controlled devices like this in Amateur stations are limited only by the imagination. ■

High Performance vhf/uhf preamps



Receive Only	Freq. Range (MHz)	N.F. (dB)	Gain (dB)	1 dB Comp. (dBm)	Device Type	Price
P28VD	28-30	<1.1	15	0	DGFET	\$29.95
P50VD	50-54	<1.3	15	0	DGFET	\$29.95
P50VDG	50-54	<0.5	24	+12	GaAsFET	\$79.95
P144VD	144-148	<1.5	15	0	DGFET	\$29.95
P144VDA	144-148	<1.0	15	0	DGFET	\$37.95
P144VDG	144-148	<0.5	24	+12	GaAsFET	\$79.95
P220VD	220-225	<1.8	15	0	DGFET	\$29.95
P220VDA	220-225	<1.2	15	0	DGFET	\$37.95
P220VDG	220-225	<0.5	20	+12	GaAsFET	\$79.95
P432VD	420-450	<1.8	15	-20	Bipolar	\$32.95
P432VDA	420-450	<1.1	17	-20	Bipolar	\$49.95
P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95

Inline (rf switched)						
SP28VD	28-30	<1.2	15	0	DGFET	\$59.95
SP50VD	50-54	<1.4	15	0	DGFET	\$59.95
SP50VDG	50-54	<0.55	24	+12	GaAsFET	\$109.95
SP144VD	144-148	<1.6	15	0	DGFET	\$59.95
SP144VDA	144-148	<1.1	15	0	DGFET	\$67.95
SP144VDG	144-148	<0.55	24	+12	GaAsFET	\$109.95
SP220VD	220-225	<1.9	15	0	DGFET	\$59.95
SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
SP432VD	420-450	<1.9	15	-20	Bipolar	\$62.95
SP432VDA	420-450	<1.2	17	-20	Bipolar	\$79.95
SP432VDG	420-450	<0.55	16	+12	GaAsFET	\$109.95

Every preamplifier is precision aligned on ARR's Hewlett Packard HP8970A/HP346A state-of-the-art noise figure meter. RX only preamplifiers are for receive applications only. Inline preamplifiers are rf switched (for use with transceivers) and handle 25 watts transmitter power. Mount inline preamplifiers between transceiver and power amplifier for high power applications. Other amateur, commercial, and special preamplifiers available in the 1-1000 MHz range. Please include \$2 shipping in U.S. and Canada. Connecticut residents add 6% sales tax. C.O.D. orders add \$2. Air mail to foreign countries add 10%. Order your ARR RX only or inline preamplifier today and start hearing like never before!

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Project Argus: An Amateur SETI Update

Dr. H. Paul Shuch, N6TX
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The SETI League, Inc. launched its *Project Argus* all-sky survey in April 1996, with the ambitious goal of real-time all-sky coverage. This SETI (Search for Extra-Terrestrial Intelligence) experiment is unique in that it employs the talents and energies of thousands of dedicated amateur radio astronomers worldwide. In its first four years, *Project Argus* has grown from five small prototype radio telescopes to one hundred operational stations, with hundreds more under construction. We are still decades away from our projected 5,000 stations able to see in all directions at once. Nevertheless, much has been learned about how to build radio telescopes on the cheap, operate them with the utmost of professionalism, and interpret received data with scientific rigor.

Sky Coverage vs. Sensitivity

The Project Argus concept is built around the use of discarded home satellite TV dishes of three to five meters in diameter.¹ When properly illuminated for minimum sidelobes at L-band, such antennas exhibit a 3 dB beamwidth on the order of 4 degrees. Thus, each antenna will subtend just over two millisteradians of sky, and a properly coordinated network of 5000 such instruments is suffi-

cient to cover the entire four pi steradian celestial sphere.

Although larger dishes would afford greater antenna gain, hence improved sensitivity and range, economic tradeoff analysis favors these more modest instruments if our goal is to achieve full sky coverage.

The available receive circuitry, coupled with the specified antennas, yields a threshold sensitivity of 10^{-23} watts/meter² in the 1.3 to 1.7 GHz *water hole* spectral region. This sensitivity is on a par with that of the Ohio State University *Big Ear* radio telescope during its long-running all sky survey.² Further, it is on a par with the sensitivity contemplated for a NASA all sky survey effort during its early planning stages.³

Argus Telescope Overview

Project Argus is a global endeavor with participants in 60 countries. Because of differences in equipment availability, there is no *standard* Project Argus hardware package, and each participating member employs such equipment as he or she may have access to locally. Nevertheless, system performance criteria have been established, and a target configuration specified, as seen as Figure 1.

The following sections discuss briefly the various items shown as Figure 1. (For further details, see *The SETI League Technical Manual*.⁴)

Parabolic Reflector

As mentioned above, by far the favored antenna for amateur SETI use is the parabolic reflector (*Dish*). The chief advantage of the parabolic reflector is that it operates over an extremely wide range of frequencies. It is limited at the low end by its diameter (which must be a respectable multiple of the longest wavelength being received, to provide reasonable gain), and at the high end by its surface accuracy (which must not deviate from the parabolic shape by more than a small fraction of the shortest wavelength being received, to maintain reasonable efficiency).

Typical satellite TV dishes generally provide reasonable performance over the 1 to 10 GHz portion of the microwave window. For reception in the 1.4 to 1.7 GHz region which is highly favored for much amateur SETI activity, the optimum dish size is on the order of three to five meters in diameter. In countries such as the US and Canada, where C-band satellite television distribution has been widely used for two decades, suitable dishes are abundantly available at low to no cost. In other parts of the world they are harder to come by, and enterprising SETI League members have acquired surplus commercial telecommunications dishes, or even built their own from scratch.

The size of the dish and the operating wavelength together determine antenna gain. As a first order approximation, the voltage gain (as a ratio) is equal to the circumference of the reflector, measured in wavelengths. Consider, for example, a 3 meter dish, which has a circumference of $(3 * \pi) =$ about 9.4 meters. At the 21 cm resonant wavelength of neutral hydrogen atoms (corresponding to the popular SETI frequency of 1420 MHz), the voltage gain of this antenna would approach $(940/21) \sim 45$. Since power ratio equals voltage ratio squared, the power gain of such an antenna would be about 2,000, which equates to +33 dBi of gain. (In fact, since the efficiency of amateur SETI antennas is generally on the order of 50%, the actual gain realized is more like +30 dBi.)

Dish size also determines beamwidth, which

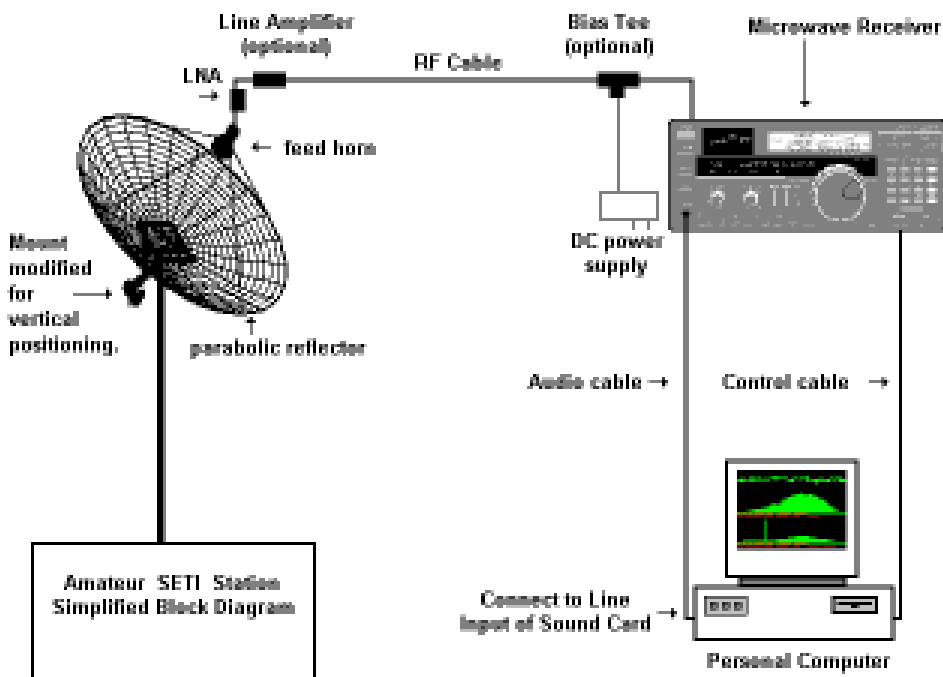


Figure 1. Amateur SETI Station Simplified Block Diagram.

dictates the degree of aiming precision required when targeting specific stars. As an approximation, half-power beamwidth in radians equals wavelength divided by antenna diameter. Thus, for our prior example of a 3 meter dish operated at 21 cm, the beamwidth is on the order of $(21/300) \sim 0.07$ radians, or 70 milli-radians, which is about four degrees. For those choosing to obtain a surplus antenna, dish condition becomes an important factor. The main consideration here is surface accuracy. In order to perform up to expectations, a dish's surface cannot deviate from the parabolic by more than a tenth of a wavelength. At 1420 MHz, that's about 2 cm of allowable surface error. If the surface of the dish is dimpled, dented, or distorted beyond 2 cm, avoid that dish! We look for something which approximates a smooth parabolic curve. If panels are missing or bent, performance is going to suffer. Next, we consider the mounting hardware. If it's rusted, you're going to have trouble getting the dish apart, and more trouble reassembling it. Weight is sometimes a consideration, as is wind loading. Where these are concerns, a mesh dish may prove more realistic than a solid one.

Few of the accessories which come along with a satellite TV dish are useful for SETI, and therefore one should not pay extra for them. C-band or Ku-band feedhorns and preamps are only of value if one is going to search in C-band or Ku-band (some of our members do; most prefer to scan the waterhole, in L-band.) TVRO receivers are great sources of microwave components, but unless other civilizations utilize exactly the same TV transmission standards we do, they're not particularly useful as SETI receivers. And a motorized mount which tracks the Clarke (Geosynchronous) orbital belt is of no value for drift-scan, meridian transit mount radio telescopes, except if modified for elevation rotation, as described below.

Antenna Mount

The beauty of mounting a parabolic antenna for SETI use is that you just can't go wrong. Since we are interested in monitoring the sky for artificial signals from beyond, the antenna merely need be pointed up — there are stars (with potentially habitable planets) to be found in all directions. So mounting an antenna for SETI use is considerably simpler than, for example, using the same antenna for satellite TV, where it must be precisely aimed at the satellite's location in the sky.

Because there are no wrong directions for SETI, many SETI antennas are simply set on the ground, *bird-bath* style, looking straight

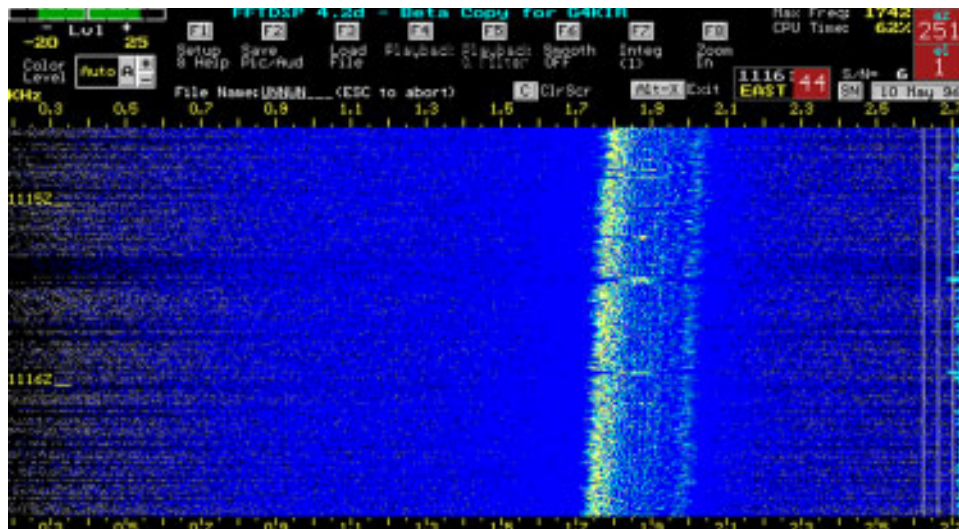


Figure 2. First Candidate Signal from Project Argus.

up. But a disciplined sky survey, such as The SETI League's Project Argus effort, requires coordinated sky coverage, and that in turn necessitates a limited steering ability for at least some of the antennas in the network.

Where steering of the antennas is desired, we need to consider two degrees of freedom: azimuth (the compass heading to which the antenna points), and elevation (the angle which the antenna's beam makes with respect to the horizon). In terms of celestial coordinates, azimuth of a radio telescope (along with a station's latitude and longitude, and the date and time) determines the Right Ascension (RA) of its target, while elevation (again, along with lat/lon, time and date) determines Declination (Dec).

Since we live on a rotating planet, the Earth herself makes a most cost effective RA rotor, as long as we are willing to be patient and let the proper portion of the sky eventually rotate into view. But since (thankfully!) the Earth doesn't rotate north-to-south, the only way to achieve Dec control is to physically rotate the antenna along a north-south line. This can be accomplished by aligning a satellite TV antenna's position rotor as a vertical (elevation) rotor.

When antenna rotors are desired, the dish positioners commonly used for satellite TV will require some source of power. The operating voltage for these positioners can often be supplied by a surplus C-band satellite TV receiver, which may also have a digital readout of dish position. Alternatively, a separate DC power supply can be used. The required voltage is typically 24 to 36 VDC, and these rotors draw anywhere from one to four amperes. Polarity determines the direction of rotation, so switching should be provided to move the dish both up and down

(or alternatively, both right and left).

Feedhorn

When radio waves strike a dish antenna, the parabolic shape of its reflector directs all the energy to a single point out in front of the dish, called its focus. The purpose of the feedhorn, which is mounted at the focus, facing the reflector, is to scoop up all this energy, and apply it to the LNA and receiver (both discussed below) for processing.

The most common feedhorn for amateur SETI use is a metal pipe, closed off at the end farthest from the dish, forming a shorted cylindrical waveguide. The horn contains a small metallic probe, connected to the center pin of a coaxial connector, to collect the energy and apply it to the input connector of the LNA. The horn is often surrounded by a metal choke ring, used to improve the efficiency of energy collected from the surface of the dish, or to block interference from entering the feed from beyond the periphery of the dish.

The chief drawback of the cylindrical waveguide feedhorn is that its large physical size actually blocks a part of the dish surface from view of its incoming signals, effectively reducing the size (and hence the gain) of the parabolic antenna. This blockage loss is most severe for small dishes, becoming almost negligible at the popular 1.4 to 1.7 GHz SETI frequencies when the dish diameter exceeds about four meters.

An alternative to the waveguide feedhorn is the helical feed, consisting of about three turns of heavy wire in a corkscrew shape, with a circumference of one wavelength at the operating frequency, and a spacing between turns of a quarter wavelength. The exact dimensions are optimized for the focal

length to diameter (F/D) ratio of the parabolic reflector used. A helix feed doesn't block the aperture of the dish to the extent that a waveguide horn does, but is more prone to interference from signals off to the side of the antenna. Both helix and waveguide feedhorn designs have been used successfully by SETI League members.

Low Noise Amplifier

The Low Noise Amplifier, or LNA, is sometimes called a preamplifier, or preamp. Its function is to take an impossibly weak signal, and turn it into a merely ridiculously weak one. The critical parameters to consider in selecting an LNA are its frequency response, gain, and noise temperature.

Frequency response determines that portion of the electromagnetic spectrum over which a particular LNA will boost the received signal, with minimum distortion or added noise. One should select an LNA with a frequency range consistent with the particular SETI station requirements. For example, C-band Satellite TV LNAs cover the frequency range of 3.7 to 4.2 GHz. Thus, they are not suitable for use in SETI stations designed to monitor the 1.4 GHz hydrogen line. Some LNAs incorporate filtering, which reduces the overall range of frequencies amplified, but which can help to reduce out-of-band interference.

Gain, measured in decibels (dB), is a measure of how much the LNA boosts the incoming signal. Although in many things *if a little is good, a lot is better*, this is not the case for preamplifier gain. In fact, excess LNA gain can actually reduce the sensitivity of the SETI receiver. The rule of thumb is that the gain of the LNA should equal the sum of the microwave receiver's noise figure (in dB)

plus the RF cable insertion loss (also in dB), plus an additional ten dB. For the average SETI station with a short coaxial cable between the LNA and the receiver, twenty dB of preamp gain is usually about right. If a very long or unusually high loss RF cable is used, a 30 dB gain LNA might be appropriate.

Noise temperature is a measure of how much additional noise the LNA adds to the SETI system. Since any actual signal has to compete with a variety of natural and artificial noise sources, the lower the noise temperature, the better. The LNAs commonly used for amateur SETI typically have between 35 Kelvin and 100 Kelvin of internal noise, when operated at average earth temperatures. Noise is sometimes expressed not in Kelvins, but as Noise Figure (in dB) or Noise Factor (a unitless power ratio).

Many commercial LNAs are provided with a choice of coaxial input and output connectors. Most SETI League members prefer to standardize on the coax connector known as Type N, since this is the connector used on most feedhorns and microwave receivers. To minimize losses, the LNA should be mounted directly on the output connector of the antenna feedhorn, with the appropriate coaxial adapter (probably a Type N male-to-male barrel adapter).

An additional consideration is how to get the appropriate operating potential to the LNA. Most LNAs operate from a DC power supply, typically in the +12 VDC range. Some designs require that this operating voltage be applied via the center-conductor of the RF cable, and some LNA vendors give you a choice between internal and separate DC feed. DC feed via the transmission line re-

quires that the microwave receiver be designed to provide this voltage, or that an accessory called a DC Inserter, or Bias Tee, be connected into the signal path ahead of the receiver, and tied in to an appropriate power supply. Although this is the scheme commonly used to power the antenna-mounted circuitry in commercial satellite TV receivers, many SETI experimenters prefer to run a separate DC cable (such as a telephone cable, speaker cable, or lamp cord) outside to the LNA, and to apply the required DC potential to it inside the SETI station. (Caution: double-check the polarity applied to this cable, as reversing the positive and negative power supply leads can damage the LNA. The center pin of the LNA's power feedthru capacitor is typically positive.)

Although most commercial (and many home-built) LNAs are metal-boxed to provide good shielding against Radio Frequency Interference (RFI), few are provided in weather-proof enclosures. To prevent damage from exposure to the elements, SETI League members often put their LNAs in plastic Tupperware® sandwich boxes. It is necessary to drill or punch holes in the plastic for the input coax adapter, output cable, and power wiring. Be sure to seal these openings with room-temperature vulcanizing (RTV) silicon rubber, which can be obtained in a tube from most any hardware store.

Line Amplifier

Need just a little more gain in your hydrogen line receiving system, perhaps to overcome coax losses? Don't waste money on cascading expensive LNAs; a satellite TV line amplifier works great!

Unfortunately, there is little standardization in terminology for the various kinds of amplifiers we will use in a SETI station. The SETI League has developed its own pseudo-standard. LNA stands, of course, for Low Noise Amplifier. Since all amplifiers used in receive systems are supposed to be low in internally generated noise, the acronym could rightly apply to all of them. *Preamp* technically refers to any amplification before the receiver, so all stages up to the receiver are in fact stages of preamplification. So to avoid confusion, we call the first preamp in the system an LNA, and all subsequent ones Line Amps.

Not all systems require a second amplifier — only those with high feedline losses to overcome. That's why we call the second amp, if used, a Line Amp. Physically, the Line Amp could be identical to the LNA (that is, we could use cascaded preamps of the same type). However, commercial line amps are

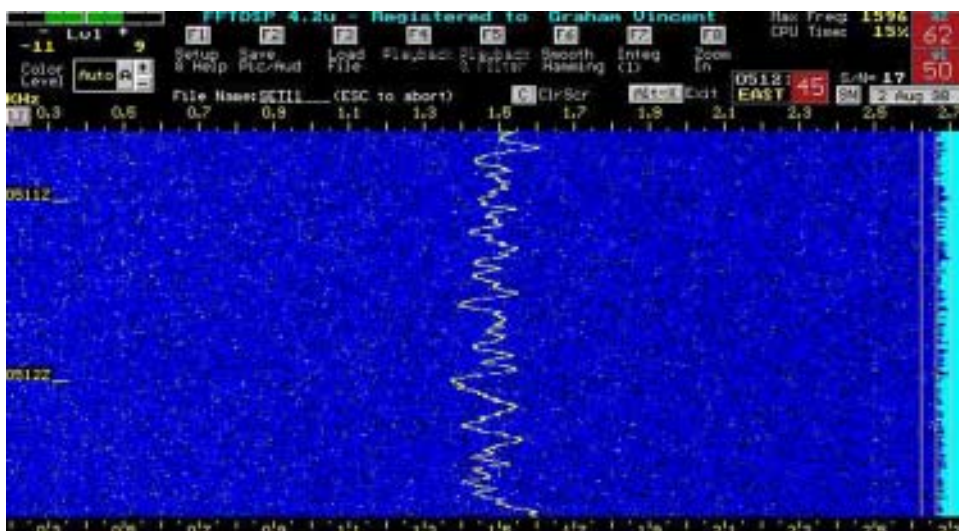


Figure 3. Terrestrial interference called wigglers observed by *Project Argus* participants.

typically optimized for higher dynamic range (with a subsequent trade-off in noise figure, since this would have been established by the prior preamplifier stages), as they will have to cope with a much higher input level than the LNA. Even so, The SETI League's designation standards refer to the application, rather than to the physical device.

Commercial TV amplifiers have type F female connectors in and out, are quite small, and require 12 to 24 volts of DC fed through the center conductor of the coax, drawing very little current. They also provide the DC back up to the LNA's center pin, which is useful if you are feeding DC up through the coax already — simply insert these amps into your existing line, with the appropriate coax adapters, and they work. This scheme will require the use of a DC Inserter, or Bias Tee, to supply the required DC voltage to the center conductor of your coaxial cable, if the station's microwave receiver does not supply it.

It should also be noted that the input and output impedance of commercial TV line amps is 75 ohms, while the interface standard for all other stages of the Project Argus station is 50 ohms. The resulting 1.5:1 voltage standing wave ratio will create minor mismatch losses, which will prove negligible so long as sufficient LNA gain exists ahead of the line amp.

RF Cable

The most common amateur SETI station configuration would place the microwave receiver, signal analysis computer and related accessories inside the house, with the antenna and LNA mounted outside, some distance away. To connect the two halves of a SETI station, we use an RF cable.

The cables we use are usually coaxial (i.e., coax cable), and we prefer those with low loss at radio (specifically microwave) frequencies. The stuff used for cable TV is cheap (pennies per meter) but pretty high loss in the 1.4 to 1.7 GHz region of the spectrum typically used for amateur SETI. The kind one would buy for, say, CB radio antennas is a little better, and a bit more costly. If one checks a local Radio Shack store or similar, one will probably find what they call low-loss coax — it's larger (perhaps 1 cm diameter) than the CB or TV type, costs maybe a dollar or more per meter, and may go under such part numbers as Belden 9913, RG-8 Polyfoam, etc. It may take special connectors (the ones most of us use are called "Type N"), which require some experience to properly install.

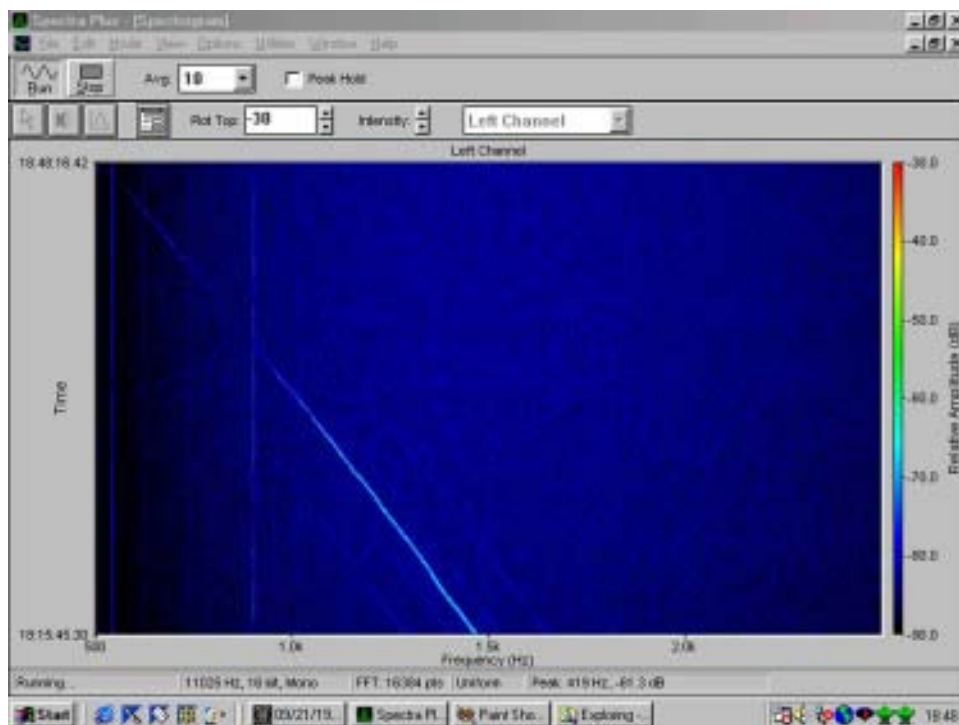


Figure 4. Low-power, spread spectrum GPS signal observed by the Author.

For any type of coax, the longer the run, the higher the loss. So we try to keep our antennas near the radio room. If this is not practical, we can do several things: use more gain in the preamp (to boost the weak signal before it suffers cable loss); follow the LNA with a satellite TV line amplifier; mount the whole receiver, or just the downconverter, outside on the dish (pumping a lower frequency through the cable is more efficient); or use specialized cables such as hardline or Andrew Heliax® (which can cost upwards of tens of dollars per meter).

Microwave Receiver

The microwave receiver takes a small, selected portion of the radio spectrum, and converts it to audio for signal analysis. Selection of the appropriate receiver leaves more to the discretion of the experimenter than any other portion of the amateur SETI system. Four distinct options present themselves. In descending order of cost, they are:

- **High-End Microwave Scanning Receivers:** These units (typified by the Icom models R-7000, R-7100, and R-8500, as well as the AOR 3000 and 5000) are multi-mode receivers which can receive AM, FM, CW, SSB, and sometimes video and digital modes. Various IF bandwidths are usually available, and these receivers are normally programmable to scan a selected range of frequencies. They typically tune from a few hundred kHz all the

way up to about 2 GHz, which actually exceeds our SETI needs. Prices are likely to start around \$2000 US, making these receivers as expensive as all other portions of an amateur SETI station combined.

- **Dedicated SETI Receivers:** One of the very few vendors of commercial radio astronomy receivers for the amateur market is Radio Astronomy Supplies of Florida. Their Seeker 2000 system is a SETI spinoff of their popular *Ultra* and *Ultra-Cyber* radio telescope receivers for continuum radio astronomy. The package includes a computer-controlled receiver, feedhorn and LNA. The receiver covers only a narrow range of frequencies, centered on the 1420 MHz neutral hydrogen line. Thus, the product is less adaptable than other receiver options, being suitable only for continuum radio astronomy and hydrogen-line SETI. It is, however, the easiest way for a prospective SETIzen of limited technical ability to get a workable station on the air, as all the user needs to add is a parabolic reflector, home computer, power supply, and a few cables.
- **Computer-Card Scanning Receivers:** The first generation were built on ISA cards, and plugged directly into one of the vacant slots on the motherboard of a personal computer. These units were prone to radio frequency interference generated by the computer itself. Later units, like the Icom PRC1000

and WinRadio 1500e, are separate boxes that plug into a computer via a serial, parallel, or USB port. They have many of the features of the high-end microwave scanning receivers, but since they rely on a companion computer for digital control, typically cost half as much.

- **Downconverter/Receiver Combinations:** Several converters are available to shift a selected portion of the microwave spectrum down in frequency, for reception in a shortwave or VHF ham radio receiver. Popular units are available from Down East Microwave in the US, and VHF Communications in Europe. Downconverters are appealing for those who already own a high-performance communications receiver, which unfortunately doesn't tune to the SETI frequency of interest. Downconverters cost about half as much as the computer-controlled receivers, but require the user to couple them to an existing receiver.

Whichever receiver scheme is selected, present practice suggests operating it in single sideband mode (either USB or LSB), and leaving it fixed-tuned, rather than scanning it across the spectrum. The reason for

avoiding frequency scanning is that the Earth is turning the antenna continually, so that the spatial dimension of the observation is always changing. Only by holding frequency constant for at least one rotational period of the Earth (that is, one day) can we avoid the problem of *too many variables*.

The bandwidth of the receiver's audio stages will typically be the limiting factor, as far as instantaneous frequency span is concerned. Many SSB receivers cover as little as 3 kHz of spectrum at a time, which is an inefficient way to search for ETI. Advanced SETI experimenters sometimes modify their receivers for up to 22 kHz of instantaneous IF and audio bandwidth, while custom-built receivers can cover several hundred kHz all the way up to a few MHz of spectrum at a time.

Digital Signal Processing

The audio output from the SETI receiver is mostly noise, both natural and artificially generated. If we are very lucky, there may be buried somewhere in that noise an intelligently generated signal of extra-terrestrial origin. But it's likely to be buried so deep in the noise that no human sense can detect it. To separate the cosmic wheat from the galactic chaff, we employ a technique known as Digital Signal Processing, or DSP.

The first step in the DSP process is to feed

the receiver's audio output into the computer, in a form that the computer can recognize — that is, as binary data. We need an analog to digital converter (ADC) to accomplish this, and the ADC of choice for amateur SETI is the PC Sound Card. Just about any SoundBlaster® compatible audio card will work with The SETI League's signal analysis software. These cards sample an audio waveform 44,000 times per second. One of the rules of information theory is that to digitize a signal, it must be sampled no less than twice for every cycle at its highest frequency. With 44 KSPS (kilo-samples per second) sound cards, this means we can digitize and analyze audio components out of our receiver up to 22 kHz in frequency.

Once the audio signal has been digitized by the sound card, it is up to the SETI computer, and its associated software, to perform the required signal analysis. Several different spectrum analysis software packages, both commercial and shareware, are being used successfully by SETI League members. They all perform Fast Fourier Transform (FFT) on receiver audio applied to a SoundBlaster (tm) compatible sound card. As you will see, there are programs to support various platforms and operating systems. Here are some of the shareware options, which are available for download via The SETI League website:

- **FFTDSP** runs under DOS. It was developed by SETI League member Mike Cook, AF9Y, for use in Amateur Radio applications, especially moonbounce (EME) communication. It has recently been successfully applied to the problem of detecting the low-power omnidirectional beacon from the Mars Global Surveyor satellite at a distance 5 Million km from Earth. It is optimized for digging weak CW signals out of the noise. The program will display a 300 to 1500 Hz spectrum to 2 Hz resolution.
- **SETIFox** for Windows 9x, by SETI League Software Committee Chairman Daniel Fox, KF9ET, is an automatic scanning and logging program meant to control an Icom R7000 or R7100 receiver. Receive output is fed to a soundblaster or compatible card configured at port 220. Power level is computed and an FFT is done on the sample. A power spectrum is computed from the result and scanned for carriers. The carrier detection algorithm looks for narrow band carriers with a power level that deviates, by a set amount, from the average power for that channel. This statistical ap-

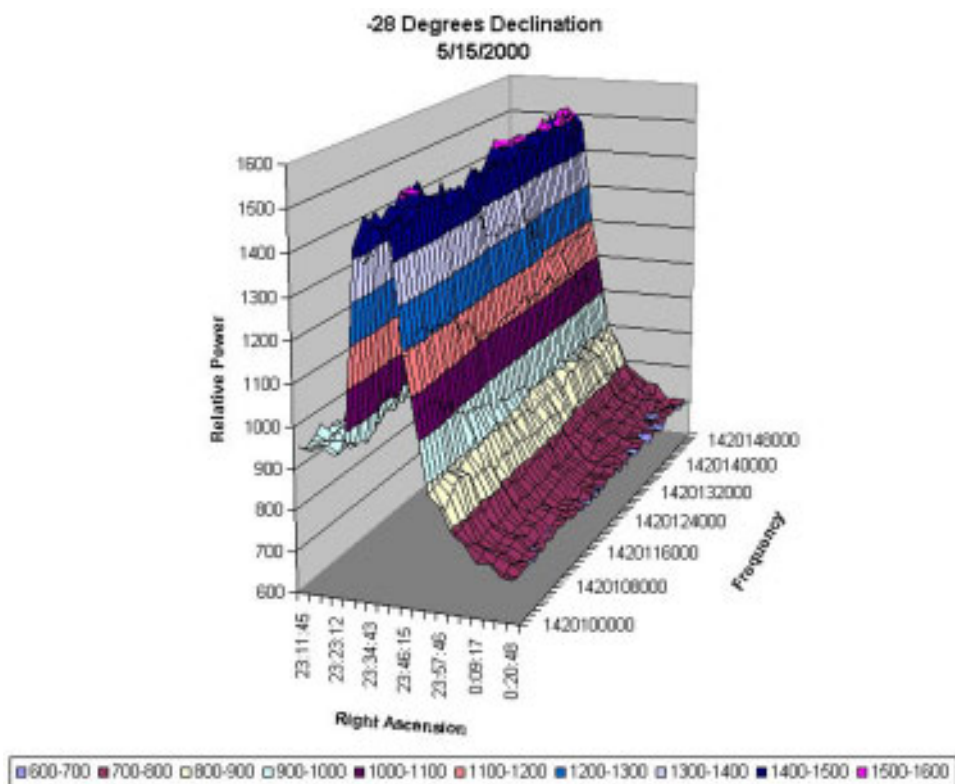


Figure 5. Example of equipment anomalies masquerading as SETI signal candidates.

proach can easily detect a weak carrier next to a large noise source since the detection is based on deviation in power level rather than power level.

- **RAOOS** (Radio Astronomy Observatory Operating System) is a suite of programs developed by SETI League Internet Committee Chairman R.J. Fear and a team of volunteers, for use in the Windows environment. It allows the user to define the system that will be driving it, using a pipe-and-filter interface. RAOOS supports centralized data collection and storage, and is a promising development for collaborative observations (such as might be practiced by multiple Project Argus participants.) Although RAOOS is not open-source, the interface standards are well documented, and users are encouraged to add their own modules to implement new functions.
- **SETISearch** for Linux, a work-in-progress headed up by SETI League Regional Coordinator Jenny Bailey, G0VHQ, is a modular, open-source approach to DSP software development. When fully implemented, it will parallel much of the functionality of the popular SETIFox program. Designed for the techie who likes to tinker with the software and perhaps add his or her own special modules, SETISearch uses as its DSP core a popular C language floating point complex FFT package developed by Phil Karn, KA9Q.

Heard So Far

Project Argus went online on 21 April 1996. Just three weeks later, two participating radio amateurs in England detected our first candidate signal (see Figure 2). Upon analysis, this event turned out to be an electromagnetic emission from a classified military satellite in low Earth orbit. The experience was significant for three reasons:

1. The signal itself was extremely weak, which speaks well for the sensitivity of the amateur equipment used. Thus, the effectiveness of the hardware was demonstrated.
2. From its Doppler signature, the shareware DSP program being used had no difficulty in identifying the signal as emanating from a low Earth orbit satellite. Thus, the effectiveness of the software was demonstrated.
3. Upon receipt of the candidate signal, the two amateurs did not contact the BBC, or the *Times of London*, or even (heaven forbid!) *The Sun*, that bastion of journalistic excellence, declaring *ET is calling me!*



Figure 6. Conceptual drawing on SETI League Array 2K.

Rather, they abided by The SETI League's published signal detection and verification protocols, and submitted their results for peer evaluation. Thus, the effectiveness of the human element was demonstrated.

Following this early experience, several dozen candidate signals have been received and analyzed by *Project Argus* participants. To date, all have been traceable to terrestrial or satellite interference, equipment malfunction, or natural astrophysical phenomena. Candidate signals are collaboratively, and posted to the *What We've Heard So Far* pages of The SETI League, Inc. website at www.setileague.org.

A few examples of interesting signals appear in the Figures 2-4. Figure 3 is a phenomenon previously observed on several occasions by professional SETI scientists. Project Phoenix scientist Dr. Jill Tarter had seen them from the Parkes radio observatory, dubbed them *Wigglers*⁵, and concluded that they represented a form of terrestrial interference. When *Project Argus* participants began to observe wigglers, they performed extensive collaborative analysis, and determined that they were L-band electromagnetic emissions originating within the very computers being used for digital signal processing! The troubleshooting challenge is evident, in that shutting down the computer ends both the interference and all documentation thereof. Wigglers in *Project Argus* stations were finally isolated to a particular model of Adaptec SCSI card. By standardizing our stations on ISA and PCI, as opposed to SCSI interface, the problem has been resolved.

Figure 4 shows the detection by the author's

personal *Project Argus* station of the low-power, spread-spectrum L2 signal from a Global Positioning Satellite. Conventional wisdom holds that these signals, intended for secure military use, are undetectable by any observer not possessing the encoding key. SETI critics use the existence on Earth of spread spectrum technology as *proof* that signals from other advanced civilizations will not be detectable by us. But in fact, the L2 signal is seen to be clearly discernible well above the noise level. In fact it is decoding of such encrypted signals which is beyond our capability. Figure 4 demonstrates clearly that detection, which is what SETI's quest for existence proof is all about, is trivially easy, providing signal strength is adequate.

Figure 5 is an example of how equipment anomalies can masquerade as valid SETI candidates. It is a wideband artifact, tens of kHz wide, which rises out of, and falls back into the noise at a rate exactly matching the drift-scan pattern of the antenna being used in meridian transit mode. After months of repeats and analysis, the SETI League member detecting this artifact traced it to thermal instability in his receiver, which caused the noise floor to rise and fall in a deceptively periodic manner.

None of the signals detected thus far is the existence proof of other intelligences, which is SETI's ultimate goal. Should a signal of probable intelligent extraterrestrial origin be detected, its existence will be confirmed by multiple observers, and it will be subject to the utmost scrutiny

The SETI League has obtained the Amateur Radio Callsign W2ETI. The callsign will be used during special events stations, including a planned calibration beacon bouncing microwave signals off the Moon.

by amateur and professional SETI scientists alike⁶ before The SETI League even considers announcing it to a waiting world.

Future Plans

Although an abundance of small dishes can, if properly coordinated, provide unprecedented sky coverage, it is when they are working as a unified whole that they will achieve their ultimate potential. SETI League engineers are currently doing preliminary conceptual work on Array2k (see Figure 6), a phased array of sixteen standard satellite TV dishes with a total of 2000 square feet of capture area. When built, Array2k will exhibit performance on a par with a single 50 foot radio telescope. It will serve as a test-bed for new SETI League hardware, as well as the software which will ultimately allow Project Argus participants around the world

to participate in our next major project, an antenna of global proportions dubbed Project ELBA (for Extremely Long Baseline Array). Array2k will also follow the example of the SETI Institute's Project Phoenix, by serving as a Follow-Up Detection Device (FUDD) for verifying the signals detected by individual Project Argus participants.

Conclusions

With one hundred participants up, and 4900 to go, Project Argus is already doing credible science. This amateur effort is also functioning as a training ground for the next generation of SETIzens, and as a test bed to develop new technologies. The SETI League is proud that our professional colleagues have followed our lead, in considering the use of inexpensive satellite TV dishes for SETI. We wish the SETI Institute and the University of California well in the development of their ambitious One Hectare Telescope, confident that it will lead to productive collaboration between SETI amateurs and professionals worldwide. For further information on the SETI League visit their WWW site at www.setileague.org.

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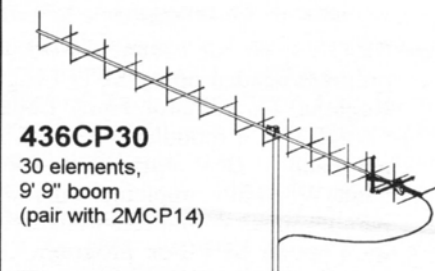
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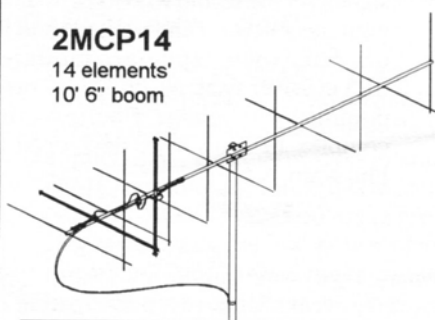
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42 elements,
18' 10" tapered boom
(pair with 2MCP22)



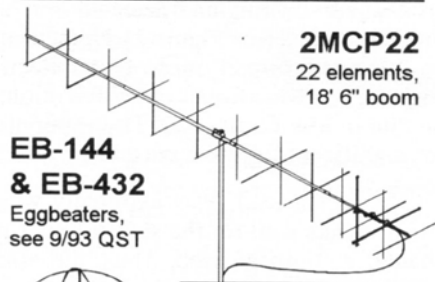
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

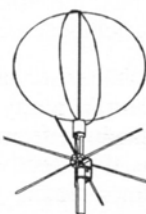
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10' 6" boom



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Phase 3D Ground Stations

Frank Sperber, DL6DBN/AA9KJ

Translation: John J. Bubbers, W1GYD

Editor's Note: This article originally appeared in the September-November issue of the AMSAT-DL Journal. At the time this article was published AO-40 was referred to as Phase 3D. Thanks to Frank Sperber, DL6DBN for allowing us to reprint this article.

One of the first goals for the AMSAT Phase 3D satellite project was to improve the communication paths by up to 10 dB in the uplink and downlink. This results in the technical requirements necessary for ground station's satellite operation.

There are seven uplink frequency regions and five downlink frequency bands useable. The multiplicity of switch modes using the IF matrix certainly will greatly influence its practical operation. In the area of digital communications there are new opportunities for using the RUDAK module, thanks to digital signal processing.

The different receivers, even various ones at the same time, can be connected flexibly to the transmitters. Two transmitters can be

operated in parallel as long as the power availability permits. Interesting connections are possible in which both transmitting stations use different frequency ranges, since all the receivers and transmitters use the same IF. Figure 1 illustrates the overlapping of the different pass-bands for the analog region of the transponder.

The Modes

A two-letter system was proposed for the future brief mode designations, which has since been accepted. Accordingly, the mode designation is composed of the identifying letters of the uplink and the downlink. Previously, Mode B (70 cm uplink, 2 m downlink) is to be identified as Mode UV (UHF/VHF). Above the 23 cm band the usual international band designations are used (L, S, C, X, K), so the combination of 23 cm uplink with 13 cm downlink would be labeled Mode LS.

Certainly, not all of the technical modes will be put into operation. For example, the 21 MHz and the 24 MHz receivers and their di-

pole antenna are suitable for use at perigee, while the X and Ka band transmitters with their directional antennas are only useful at close to apogee. Likewise, Mode HX is quite unrealistic.

Consideration and significance for the northern hemisphere are:

- Mode-VU: Previously Mode-J, was very popular on AO-13 in parallel to Mode-L with hand-held 2 meter systems or with a 2 meter transceiver plus down-converter to 10 meters. Drawback: Interference from numerous PACSAT uplinks.
- Mode-LU: previously Mode-L, can be operated with less power than AO-13 because of higher antenna gain, no interference from other uplinks, and complete 250 kHz transponder bandwidth.
- Mode-US: previously Mode-S, very popular on AO-13, small receiving antennas (parabolic, helical), nearly interference-free reception, downconverter either already on hand or readily available.
- Mode-LS: combines the advantages of the L-band with the downlink advantages of the S-band, may become the standard mode of the future.
- Mode-UX: eventually has a cost advantage for radio amateurs from the X-band that is used by direct TV satellite technology.
- Mode-LX: the alternative to UX with smaller uplink antennas.
- Mode-SX: the mode for microwave enthusiasts with an S-band transverter.
- Mode-CX: mainly for the microwave specialist who can generate 5 W or has room for a large parabolic reflector.

Those modes with a downlink in the two-meter band cannot be recommended in RF intensive areas in our region and therefore were not further considered in this review.

The Uplink

The desired improvements in the link paths are related to the available transmitter power and the size of the antenna on the uplink.

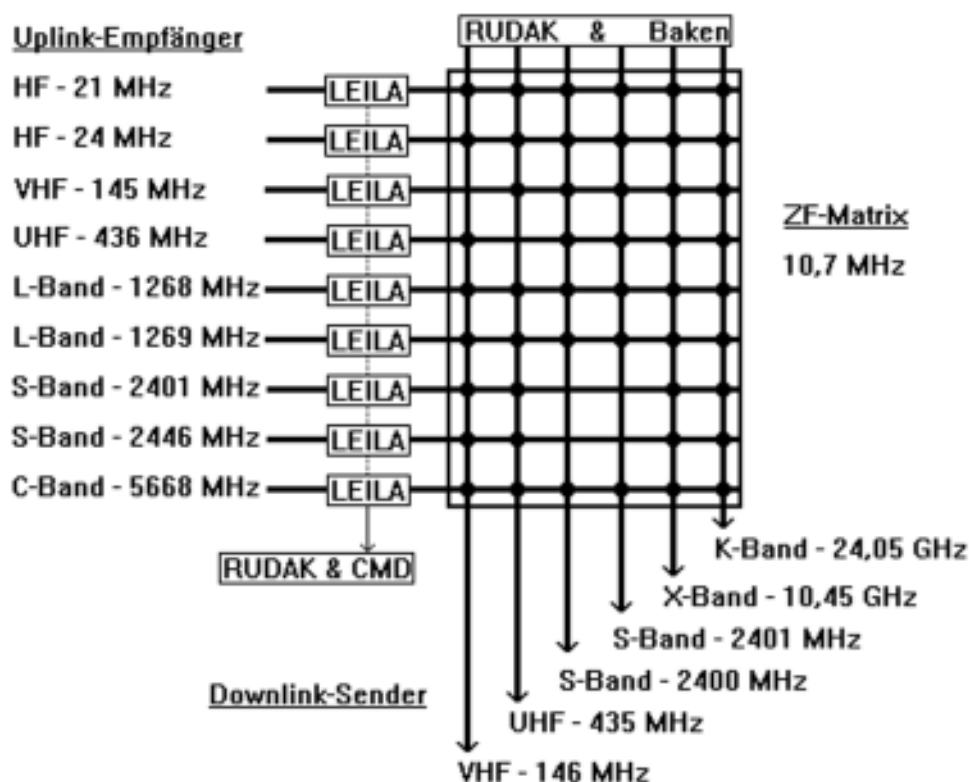


Figure. 1: The IF matrix in Phase 3-D, the dotted intersections indicate the possible transponder communications combinations.

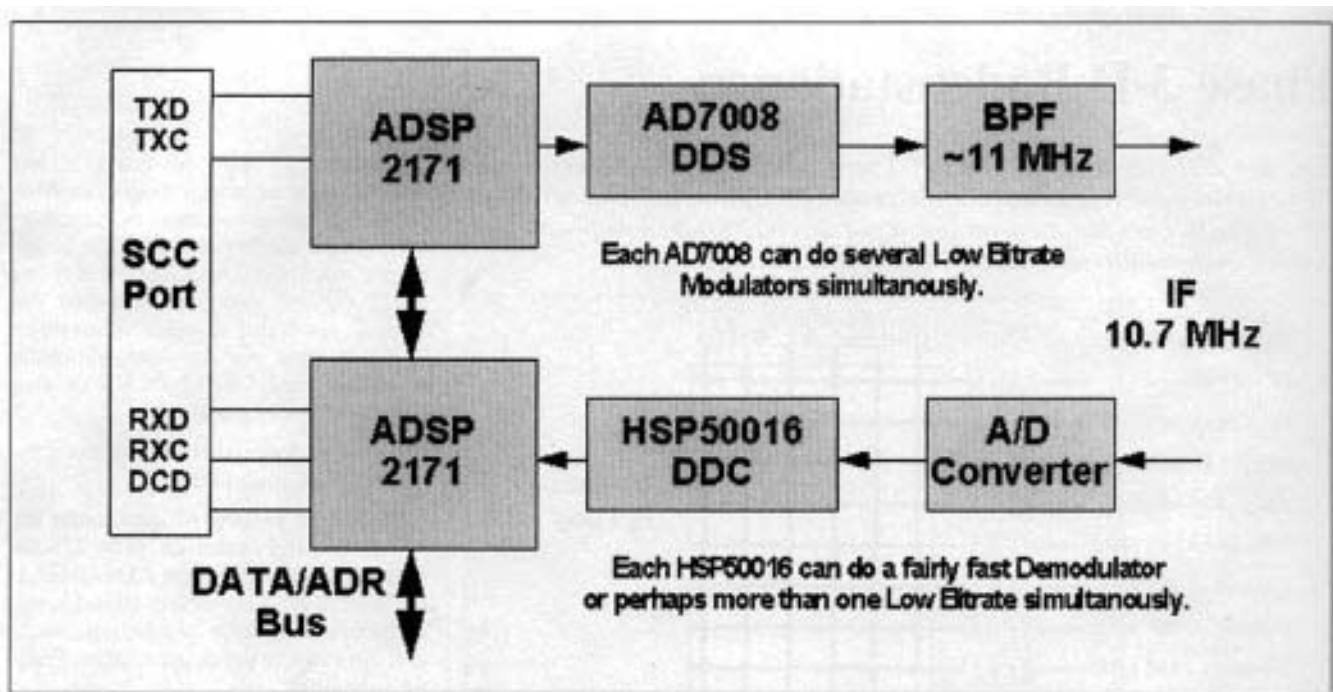


Figure. 2: The Phase 3-D DSP Modem. (Pictorial: Peter Gülzow, DB2OS)

The related results are in table 2 for the computation of the link budgets and several examples for the appropriate ground stations. The computations are based primarily on an SSB contact.

The starting point for the computations is the noise temperature, which the satellite sees in the earth's direction. The complete received noise power, aside from the system noise of the satellite's components, is primarily the thermal noise of the earth ($0^\circ = 273\text{ K}$), since the antenna's main lobe is aimed only at the earth.

On the lower bands there is a certain amount of HF pollution in addition. Additionally, the antennas will see a part of the cold sky, which is really not so cold at these frequencies. On page 9-1 in the *Satellite Experimenter's Handbook* by Martin Davidoff there is a dia-

gram that shows the noise temperatures of the sky versus frequency. This noise temperature can be recomputed into noise power. The usable signal from the earth must exceed this noise.

Part of the link improvement of Phase 3D relative to AO-13 is in the increase in the signal/noise relationship. This makes the signal easier to understand, and helps to reduce articulation loss because of excessive noise. In digital modes this is diminished by the improved S/N relationship relative to the frequency of bits lost. If a S/N ratio of 17 dB has been assumed for AO-13, then 23 dB can be assumed for Phase 3D. This depends on the achievable downlink conditions, as will be seen below.

The signal strength is figured from the noise power and the S/N ratio that must be con-

sidered at the satellite receiver's input. The received signal from the antenna can be smaller depending on the gain of the antenna. If the spreading losses or the path loss between satellite and ground station are added together the result is the uplink radiation power requirement (ground station PEP). The table shows several examples for a corresponding antenna and transmitter output power on the ground. Circular polarization is assumed throughout.

As can be seen, the installations, relative to AO-13, are noticeably smaller, because of the improved signal/noise relationship. This is where Phase 3D achieves its goal.

A further improvement over operation on AO-13 is the aim of LEILA (LEIstungs-Limit-Anzeige ~ *Power Limiting Indicator*). LEILA actively recognizes the problem of the receiver sensitivity from overly strong stations (a.k.a. crocodiles). These stations will then be put on notice about their excessive output power with a siren-like signal and will be requested to reduce power. If the power remains too high, the signal will be tuned out with a notch filter that has a depth of 20 dB. In order to be heard again, the offending station would have to increase power by a factor of between 10 and 100 times. The receiver sensitivity always achieves its optimum value, in any event.

The Downlink

A special meaning is attached to Phase 3D

Downlink (MHz)		145	435	2401	10450	24048
Uplink	Abbreviation	V	U	S	X	Ka
21 MHz	T	TV	TU	TS	TX	TK
24 MHz	H	HV	HU	HS	HX	HK
145 MHz	V	-	VU	VS	VX	VK
435 MHz	U	UV	-	US	UX	UK
1270 MHz	L	LV	LU	LS	LX	LK
2400 MHz	S	SV	SU	-	SX	SK
5650 MHz	C	CV	CU	CS	CX	CK

Table 1: An overview of the modes.

for the path from satellite to earth. Only what can be heard, can also be worked. Table 3 shows the calculations for a link-budget for two example stations.

The satellite's transmitter power and its antenna gain are deciding factors to determine the signal power arriving on the earth. Together they result in the total PEP-radiation power of the satellite. This power is divided into many occupied signals in the linear transponder including the beacons and RUDAK. Each individual signal has only a part of the peak power available.

The power for each QSO is 10 to 16 dB below the total power according to AMSAT-DL sample calculations. Including the path losses in the calculations gives the signal power needed for the reception of a ground station (ground PEP). The desired signal/noise ratio at the ground is determined by the noise power, the signal bandwidth and the antenna gain. In the table the results are shown for two sample calculations, one for a fixed installation and a second for a portable installation.

In contrast, the noise temperatures of the sky is lower on the high frequency band's uplink, since the satellite's main lobe looks mainly at the cold sky. Naturally, it is different during the day, when the satellite is located in the direction of the sun. The sun delivers a distinct noise increase, which leads to a poorer S/N.

Even on the downlink paths Phase 3D will be able to deliver the anticipated expectations from the increased transmitter power and the antenna gain. In comparison to OSCAR-13 the antennas will be distinctly smaller for the same S/N ratio, at times even usable for mobile operation. On the other hand, distinctly better signals can be achieved so stationary antennas for Phase 3D will not have to be as large as they were for AO-10 and AO-13.

Bandwidth Phenomenon

Until now the considerations have been on communications using regular SSB bandwidth of 2.5 to 3 kHz. The bandwidth is defined in the equation

$$W_n [\text{mW}] = k \times T_e \times B$$

Where:

Boltzman's constant $k = 1.38 \times 10^{-20}$,

System temperature (T_e) is in Kelvin

Bandwidth (B) is in Hz in the received noise

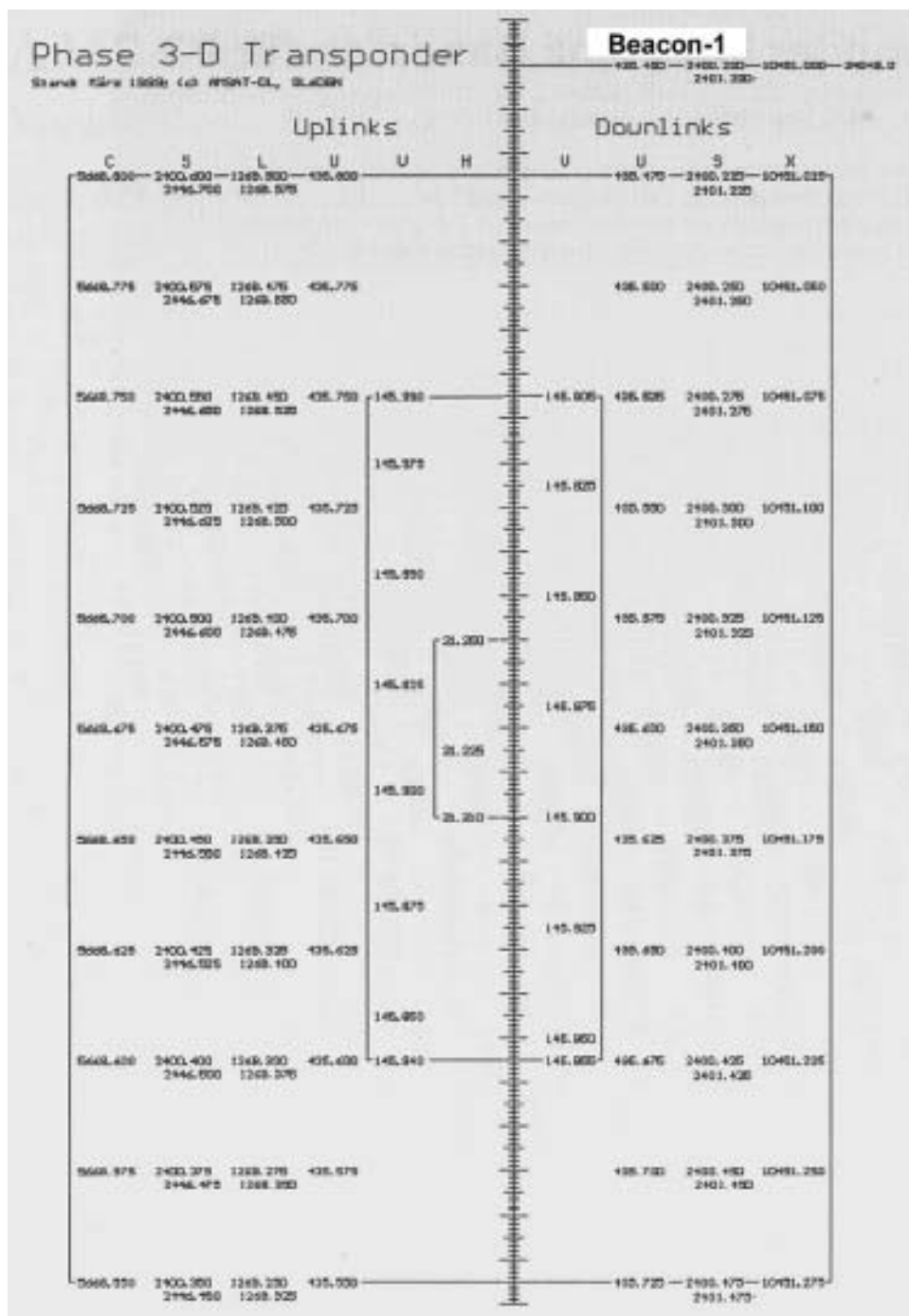


Figure. 3: The band pass ranges of the linear transponder for individual bands

power.

The narrower the bandwidth, the greater the S/N ratio; for an equal S./N the power requirement is reduced. Table 4 shows the differences between SSB and several other bandwidths.

As can be seen, this has especially meaningful implications for the wider bandwidths of the digital working modes (9,600 bps FSK, for example). To equalize the satellite's downlink signal, the available transmit power must

be increased on the uplink by the ground station, which would be similar to the current power requirement for AO-13. Luckily, digital modes require lower S/N ratios than the human ear needs for easy understanding. In reference to SSB, 3 dB will be adequate for 9,600 bps operation.

At lower transmission rates, such as 1,200 bps-PSK-modes, the normal SSB communications power will suffice, which makes this data rate attractive especially for the short data exchange in portable operations.

	145 MHz	435 MHz	1260 MHz	2400 MHz	5650-MHz
Noise Temp.	1000 K	500 K	300 K	300 K	300 K
Noise Power	-165 dBW	-168 dBW	-170 dBW	-170 dBW	-170 dBW
RX-Signal Power @23dB S/N SSB	-142 dBW	-145 dBW	-147 dBW	-147 dBW	-147 dBW
Antenna Gain Sat	8 dBi	13 dBi	18 dBi	20 dBi	20 dBi
Loss	170 dB	179 dB	188 dB	194 dB	201 dB
PEP-Ground	20 dBWi	21 dBWi	23 dBWi	27 dBWi	34 dBWi
Samples	10W-7 Ele 50W-GP	10W-10 Ele 50W-Dip/Refl	10W-8T Helix 5W-60cm Dish 50W-Dip/Refl -2dB	5W-60 cm Dish 1W-1.8M Dish	10W-60 cm dish

Table 2. Uplink Budgets.

	146 MHz	435 MHz	2400 MHz	10450 MHz	24048 MHz
PEP Xpndr	100 W	150 W	50 W	50 W	1W
Sat. Ant. Gain	8 dBi	13 dBi	20 dBi	20 dBi	23 dBi
PEP Sat.	28 dBWi	34 dBWi	37 dBWi	37 dBWi	23 dBWi
PEP/QSO (-13 dB ca)	15 dBWi	21 dBWi	24 dBWi	24 dBWi	17 dBWi (only 2-4 QSO's)
Loss	170 dB	179 dB	194 dB	207 dB	214 dB
PEP-Ground	-150 dBWi	-158 dBWi	-170 dBWi	-183 dBWi	-194 dBWi
Ground Ant. 1	10 dBi	13 dBi	20 dBi	33 dBi	40 dBi
	7 Elements	10 Elements	60cm Dish	60cm Dish	60cm Dish
Signal Power QSO in SSB	-145 dBWi	-145 dBWi	-150 dBWi	-250 dBWi	-254 dBWi
Noise Temp. =	1000K	500K	150K	150K	300K
	3dB NF	3dB NF	1.5dB NF	1.5db NF	2.5db NF
Noise Power in SSB	-165 dBW	-168 dBW	-173 dBW	-173 dBW	-170 dBW
S/N	20 dB	23 dB	23 dB	23 dB	16 dB
Ground Ant. 2	5 dBi	5 dBi	13 dBi	27dBi	
	Dipole w/ Ref	Dipole w/ Ref	8-turn Helix	30cm Dish	
Signal Power	-150 dBWi	-153 dBWi	-156 dBWi	-156 dBWi	
Noise Temp. =	1000K	300K	100K	150K	
	3dB NF	2dB NF	0.9dB NF	1.5dB NF	
Noise Power in SSB	-165 dBW	-170 dBW	-174 dBW	-173 dBW	
S/N	15 dB	17 dB	17 dB	17 dB	

Table 3. Downlink Budgets.

Uplink	V	U	S	X - Downlink	Uplink	V	U	S	X - Downlink
V	-	x	.	x	V	-	x	.	x
U	x	-	x	.	U	x	-	x	.
L	.	x	.	x	L	x	x	x	x
S	.	x	-	x	S	.	x	-	x
C	.	x	.	x	C	x	x	x	x

Table 5. Modes covered with 2 and 3 Band Transceivers.

Equipment

The AMSAT-DL Journal article "The Phase-3D Transponder Combinations from the Users Viewpoint", which appeared on page 22 of the 2/95 issue, discussed several special attributes for equipment use. As a result one can determine that beginning above the 13 cm band the microwave frequencies will be translated to a lower frequency close to the antenna, similarly for the transmitter, close to the antenna as well. This is the only way the cable losses can be held to a minimum. The mode combinations in Table 5 can be covered with current converters depending on the basic transceiver (2-band or 3 band including 23 cm).

Currently there are commercial units or kits available for all those bands to be covered with a transverter or a converter. Construc-

tion descriptions have often been published in the German specialty publications (CQ-DL, UKW News, DUBUS). More components will certainly become available with the increasing popularity of the satellites.

A classic area of experimentation, namely antennas, has been opened with again Phase-3D, especially for the satellite amateurs. Finally it is important, to cover the multiplicity of bands with a minimum of antennas. There is already a solution to this problem (Simple Parabolic Antennas, ON6UG in the AMSAT-DL Journal 4/89, page 10 and AMSAT-DL Journal 3/00, page 6). If the calculations in the above table are taken as basic, then a 60 cm parabolic reflector with multi-band feeds could become the standard system for most applications, paired with a short Yagi for 145 MHz and one for 435.

BW	Mode	dB
0.5 kHz	CW	+7
2.5 kHz	SSB/PSK	0
20.0 kHz	FM/FSK	-9

Table 4. Power differences for different signal bandwidths.

Digital Matters

For most of the future Phase 3D users digital modulation mode of 9600 bps FSK will be used, according to the above bandwidth considerations. Only a small user base will be using higher data rates, considering the program capability of RUDAK. The technology for 9600 bps FSK has been widely disseminated in the meantime, and thanks to simpler TNC's and supplementary modems in various configurations are available without difficulties. Since there are several hard-wired modems in this configuration on Phase 3D, quite soon after the launch there should be an opening to this mode. Software for this mode has yet to be written for the other modems on board.

The 1200 bps-FSK mode would be reasonable for most satellite users, as it is known from the Fujis and MicroSats. It would be advantageous for stations with small antennas and low output. Unfortunately, there are only still quite expensive DSP solutions on the market. Kits or PC boards for simple modems are not available in Europe at the moment.

A universal and flexible solution to all the modulation modes that Phase 3D will ever be able to offer would be a modem containing DSP/DDC/DDC to the satellite. As soon as new software for the satellite came into being, the user could load it without many modifications through an additional data and address bus in the terrestrial modem. The one catch: the DSP signal paths work directly at the IF level at 10.7 MHz. It would have to be coupled into the transceiver on hand at the IF. But the nature of Amateur Radio is experimentation.

Immediately After the Launch

It will take until Phase 3D's first so-called summer-period with good illumination and adequate antenna pointing until transponder operation will be possible. The above considerations are for the apogee in the final orbit with three-axis stabilization. Until then, things are a little different. First Phase 3D is in a transitional orbit with an apogee height of nearly 59,000 km which will add 1 dB of loss, and which will have to be compensated on earth. We also have to deal with

skint-angles and beam-width loss while Phase 3D is spin-stabilized.

As long as the solar panels are not deployed the transponder can operate only with reduced power. Roughly only -5 dB can be put into service, since only one third of the energy is available. Which receivers and transponders will be operational have to be tested during commissioning.

Higher power is required for transmit and receive until the final operation position. The purchase of a heavy and expensive final stage is not justified in the transition time, since the transponder presumably can be operated only for four months.

Summary

AMSAT Phase-3D offers the committed satellite amateur unimaginable opportunities for experimentation and communications in its final orbit, which will once again show the high level of Amateur Radio service. We hope that Phase 3D, now AO-40, will reach a useful orbital path and that its opportunities will be used intensively and responsibly. ■

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Call for Papers – AMSAT-NA Annual Meeting and Space Symposium

Steve Diggs, W4EPI

The 2001 AMSAT-NA Annual Symposium and Space Symposium is scheduled to be held 5-6 October 2001 in Atlanta, Georgia. This announcement is the first call for papers to be presented during the Symposium. Papers may be presented by the author during the Symposium, or simply offered for inclusion in the symposium proceedings publication. The subject matter should be of general interest to Amateur Radio operators involved in satellite communications. Suggested topics might include: operating techniques, antenna design and construction, spacecraft design and construction, current mission status, proposed missions, telemetry acquisition and relay, satellite microwave projects, etc. A brief one-page abstract of the proposed paper, in outline format, should be submitted as soon as possible. The final date for abstracts is 30JUN01. Authors will be notified of paper acceptance after 30JUN01 and camera-ready papers must be received no later than 15AUG01. Electronic submittal is preferred. File format must be either MS Word-compatible or plain text. For security purposes, please ZIP your document file, and send it as an email attachment. Address email to Steve Diggs, W4EPI at w4epi@amsat.org. Steve's address information is correct in the callsign database.

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Field Ops Update: AMSAT Area Coordinators Listing

Barry A. Baines, WD4ASW, wd4asw@amsat.org

Once again we present our annual listing of AMSAT-NA's Area Coordinators. In this issue you will find a listing of the 179 Area Coordinators in the US, Canada, and US Territories (plus 5 country representatives) who donate their time and energy to help represent AMSAT within their respective communities. These volunteers may give programs to local clubs, serve as 'Elmers' to folks getting started in amateur satellites, and establish AMSAT nets on local repeaters. Other activities that Area Coordinators have done include organizing local AMSAT gatherings and supporting AMSAT Field Day activities. They serve as 'Ambassadors of AMSAT' in that they become the local contact for people needing information on the amateur satellite program. Through close coordination with AMSAT-NA Office Manager Martha Saragovitz, who provides AMSAT banners and materials when requested, they represent AMSAT at hamfests and swapmeets as well as lead AMSAT presentations at these gatherings as well. A number of volunteers have done AO-27 and UO-14 demonstrations at hamfests, for example, which always generates interest and enthusiasm and which demonstrates to their communities what the amateur satellite program is all about.

AMSAT-NA has been blessed by a number of people who have stepped forward to volunteer as Area Coordinators around the country. We currently have Area Coordinators in 49 states and 4 Canadian Provinces, as well as Guam, Puerto Rico, and the US Virgin Islands. Given the need to show the flag throughout North America, we continue to look for volunteers everywhere. You will note that there is only one state where we don't have a designated Area Coordinator (Wyoming). There are eleven other states in which there is only one Area Coordinator. Even in states where we have multiple Area Coordinators, we still lack Area Coordinators in heavily populated areas nor do we enjoy even distribution of Area Coordinators around a given state. Field Operations representation is particularly needed in areas such as California (Los Angeles), Florida (Panhandle), Illinois (Chicago), Massachusetts (Springfield-West), New Jersey (Newark and the Northern half of the State), New York (NYC and suburbs), Ohio (Cincinnati, Cleveland), Pennsylvania (Allentown/Northeast), Tennessee (Nashville-Memphis), North Carolina (Raleigh-Durham to Wilmington), and the DC area. In Canada, we can also use support in the Eastern Provinces (Quebec, Newfoundland, New Brunswick, Nova Scotia) as well as Saskatchewan and Manitoba. The need for local AMSAT involvement in these areas is a need that has been identified in the past.

The importance of having Area Coordinators in these areas as well as improving coverage in existing areas cannot be understated. AMSAT's ability to increase interest in the amateur satellite program is dependent in part upon creating and maintaining both individual interest and general knowledge within the amateur radio community of using amateur radio satellites. As was noted in past issues of *The AMSAT Journal*, AMSAT has not been represented at several large hamfests because we don't have points of contact close enough to take advantage of these opportunities. Likewise, when contacted by several clubs looking for local AMSAT representatives to provide a club presentation or for technical support, we could not meet their requests on the local level. Our lack of volunteers to address these situations results in failure to develop support for the amateur satellite program, lost membership opportunities, and missed revenue through distribution of AMSAT materials. More importantly, not being seen means that our message is not being heard.

An additional consideration is the availability of volunteers to serve as local contacts regarding AO-40 operations once the satellite's condition is fully verified. AMSAT needs a cadre of AMSAT members who are prepared to build awareness of Amateur Radio's newest satellite. As information is made available, we can use some assistance in educating the amateur population of where they can get this information and encourage new satellite operators to try AO-40 once it is in general amateur service.

To help provide our area coordinators with presentation materials, we have developed a "Field Operations Resource Toolkit" on CD-ROM that will be mailed to each Area Coordinator in North America by the beginning of April. The CD-ROM contains full-featured PowerPoint presentations that cover AO-40, Amateur Radio on the International Space Station, and "Introduction to Amateur Radio Satellites." Each of these briefs is suitable for both club presentations and serving as a 'slide show' for displaying at an AMSAT display at a hamfest. There are also WAV files of various satellite related activities, such as MIR and the digtalker on the Fuji satellites. We also continue to maintain the AMSAT Resource Guide, which is an excellent summary of information sources on amateur radio satellites that is appropriate for use as a handout at club presentations and distribution to new members.

You can check the latest version of the Area Coordinators Listing by going to the AMSAT web page (www.amsat.org) and selecting "Find Your Local Area Coordinator." Links are also available under the

"Who's Who page", on the AMSAT-NA organizational information page, and in the A-to-Z index. Thanks to the efforts of Chas Richard, W4HFZ, and Jim Sanford, WB4GCS, we can now provide a means for both newcomers and our AMSAT members to obtain this information as easily as possible as well as provide a means for our Coordinators to verify the accuracy of their individual listing. Should you have thoughts or comments about improving the Field Ops information pages on the AMSAT web site, please take a moment to convey your suggestions to me.

Our list of volunteers includes "Country Representatives" who are AMSAT-NA members living outside North America and perform fulfill the same functions as Area Coordinators in North America. These volunteers live in countries that don't host a national AMSAT organization. Having these individuals identified on our listing is another means of supporting the Amateur Radio satellite program as well as provides a mechanism for providing technical and informational support for individuals who are willing to encourage amateur radio satellite activities in their local communities.

Thinking of joining the Field Operations Team? The qualifications needed for being an Area Coordinator are simple: You must be a current member of AMSAT-NA, be willing to work with people, and have an interest in representing the organization as your time and interests permit. In order to maintain contact with members of our Field Ops Team and provide them with support materials as needed, we also require each Area Coordinator have Internet electronic mail capability. E-mail provides an easy and cost effective avenue for distributing information, sharing ideas, and responding to requests for support. Given the variety of satellites in current use and the diversity of interests, Area Coordinators are not expected to know everything about the amateur satellite program. What is important is that each Area Coordinator be willing to find answers to questions and follow up with individuals looking for assistance. That's why we require electronic access, so that everyone can get information from other Area Coordinators and respond to queries in a timely manner.

If you are interested in serving as an Area Coordinator or learning more about the Field Organization, please contact me via:

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[AMSAT Journal Telemetry continued from page 2]

- 937 command dairies uploaded in operating SUNSAT
- 241700 telecommands executed successfully
- 161.144 Mbytes of whole orbit data (WOD) downloaded
- 94868 GPS data points downloaded in support of JPL
- 3.144 Mbytes APRS digilogs leading to a new activity
- 1.656 Mbytes of Magnetometer data
- 888 Kbytes international school experimental data
- 7.052 Mbytes of data for the star camera experiment
- Several hours of PAL videotape data of Southern Africa

During the first year of SUNSAT's operations, the orbit provided ideal lighting conditions for imaging, and eclipse periods during every orbit to cool down the satellite. The various functions of the satellite were commissioned and operated, such as the high-resolution camera, the PAL video camera, the amateur radio communications systems, the attitude control system, the science experiments and the school experiments. However, the non-ideal drifting orbit plane eventually exposed SUNSAT to continuous sunlight. This particular orbit was determined by the requirements of the Danish Orsted satellite, together with which SUNSAT was a secondary (and free) payload on the launch vehicle. When the satellite became exposed to full sun

continuously, the SUNSAT operations team started taking measures to alleviate serious problems of high operating temperature and overcharging of the batteries, by continuously re-orientating the satellite. Amateur Radio services were still provided by SUNSAT during this phase and science and control systems experiments were conducted. However, imaging was discontinued due to poor lighting conditions. This non-eclipsing situation continued for five months before the orbit plane again started to cause sun eclipses.

When the eclipses restarted, it was clear that battery capacities were low (fast voltage drop under load), as evidenced by some of the on-board processors resetting during eclipses. The assumption of a typical NiCd memory problem due to overcharging led to procedures that reconditioned the battery cells via a number of forced fast discharges. This exercise was successful to the extent that the resultant improvement of battery capacity enabled SO-35 to once again function throughout full eclipses without processor resets.

Operations were back to normal when, after the communications pass of Friday, 19 January 2001, radio contact ceased altogether. It is unlikely that battery failure is the cause, since there was no evidence of gradual power failure from the telemetry of the last few orbits of normal operations, and even during direct sunlit passes, SO-35 is not reacting. It is also unlikely to be a solar cell malfunction, since this would also have been evident from the solar cell current measurements and a lack of battery charging over a number of orbits.

The functionality of the ground station was also verified through communications with other amateur satellites, up- and downlinking via both

UHF and VHF frequency bands. All possible combinations of the RF-Modem-Telecommand-subsystems were attempted unsuccessfully. All other communication paths to and from SUNSAT were thereafter investigated systematically, but without success. This includes efforts to use telecommands directly on a command-for-command basis (open loop) to place the subsystems in recognizable states.

From the tests conducted, the possible failure scenarios in order of likelihood, are:

- A possible failure cause would be simultaneous multi-point failures. However, the access experiments listed above tested all possible single point failures through previously used redundant routes. The probability of a simultaneous multi-point failure is consequently rather low.
- A battery cell or main power diode could have burst and caused physical mechanical damage in the power supply system, since limited communication would have been possible with either battery or solar power.
- An external object in space could have caused major physical damage to SUNSAT.

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